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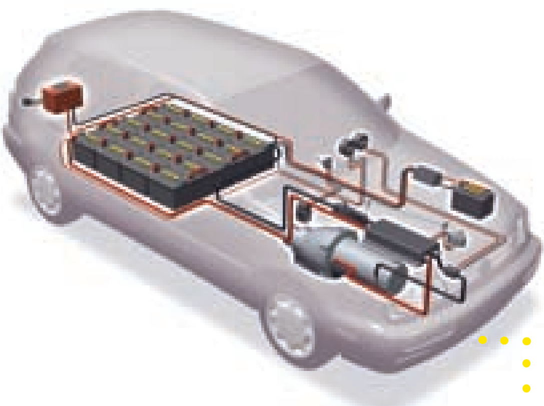

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Clockwise from lower left: Courtesy www.conergy.us; Dan Redmond; Steve Cowden; Josh Root; courtesy www.solarthotusa.com; courtesy Chris Greacen

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Kathleen Root with her get-around-town car, an all-electric Zenn that she charges with renewably generated electricity from her 3.5 KW grid-tied PV system.

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Here Comes

Sunshine

Snow. Overcast. Rain. More snow. Days. Weeks. Months. If you live with a solar-electric system, you can surely relate to the anticipation that comes as the days get longer—with spring right around the corner, and those soon-to-be, endless sun-filled days of summer not far behind. Living with solar energy—off grid or on—creates a heightened awareness of the changing weather and seasons.

Here in southern Oregon, it's been one of the snowiest winters on record and the local *Home Power* crew has been toughing it out, waiting for the sun. Some of us have been snowed in at our off-grid homesteads for more than a month. Others have been snowed out for just as long. Snowshoes have replaced pickup trucks.

For those of us living off-grid, the long stretches of sunless weather come with increased conversations about the homestead's energy management—how much to dial back appliance use, when it's time to use the backup generator, and remembering to keep a close eye on the battery state-of-charge monitor.

While this might sound like a big hassle, and at times it can be, adapting our daily routines to the energy that's available has a satisfaction all its own. When the sun finally does break through, and it always does, its light seems that much more powerful.

When access to electricity simply means throwing a switch to tap into what seems like an endless supply of energy, the impact is out of sight for most of us in the developed world. The effects of nonrenewable sources of electricity generation—such as coal, natural gas, or nuclear power—lie hidden in other counties, states, and even countries.

It's also *out of mind* for a great many people, although it doesn't have to be. Whether we live on grid or off, living with renewable energy brings us one step closer to getting a grip on where our energy comes from. The weather report becomes more significant. Outside, your solar array, wind genny, or microhydro turbine quietly harvests the renewable energy that surrounds us. Inside, when you flip on the light switch, you know that it matters how you choose to use, or not to use, the energy you have.

—Joe Schwartz for the *Home Power* crew

Think About It...

"Winter grey and falling rain, we'll see summer come again… gonna happen every time."

—Grateful Dead, "Weather Report Suite: Part One" (1974)

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Ask the EXPERTS!

Mismatched Modules

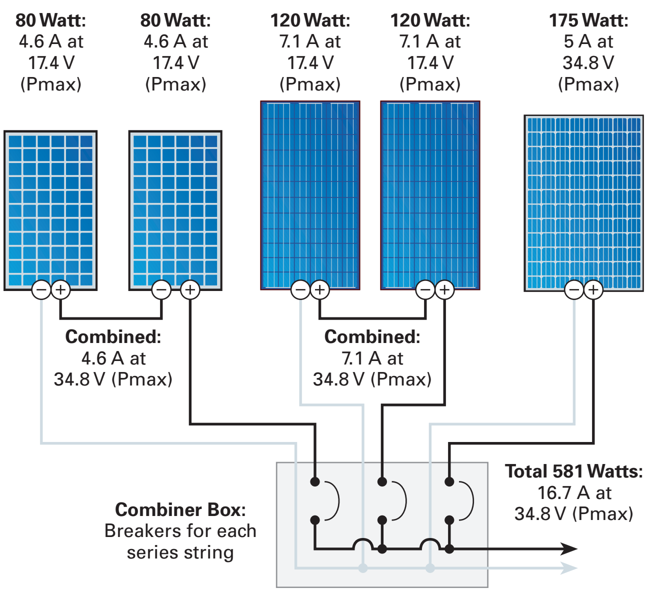
We need to upgrade the solar-electric system for an off-grid home. The existing array consists of two 80-watt modules rated at 21.8 Voc (open-circuit voltage) and 4.85 Isc (short-circuit current), and two 120-watt modules rated at 21.5 Voc and 7.45 Isc. The owners would like to add one 175-watt module rated at 44.4 Voc and 5.3 Isc. The array sits on a hill that's 160 feet from the batteries and inverter.

We put each 80-watt module in series with one 120-watt module and wired those strings to the combiner box. We ran the 175-watt module direct to the combiner. All three strings were paralleled for the 160-foot run down to the power shed to the charge controller. Is there a big loss incurred by putting an 80-watt module in series with a 120-watt module? I was thinking the amperages would average out. Is that true, or does the 120-watt module perform like an 80-watt module in that configuration? Should I have put the 80s in series and the 120s in series? What would have been the most efficient way to wire these modules for a 24-volt nominal system?

Alex & Dave Cozine, Brothers Electric & Solar • Tacoma, Washington

The way you wired the modules will work, but it won't supply the greatest amount of input current. Your mistake is assuming that the amperages would average out. If you connect modules of different amperages in series, the voltages will be cumulative, but the currents will approximate that of the smaller module.

Good: Similar PVs in Series

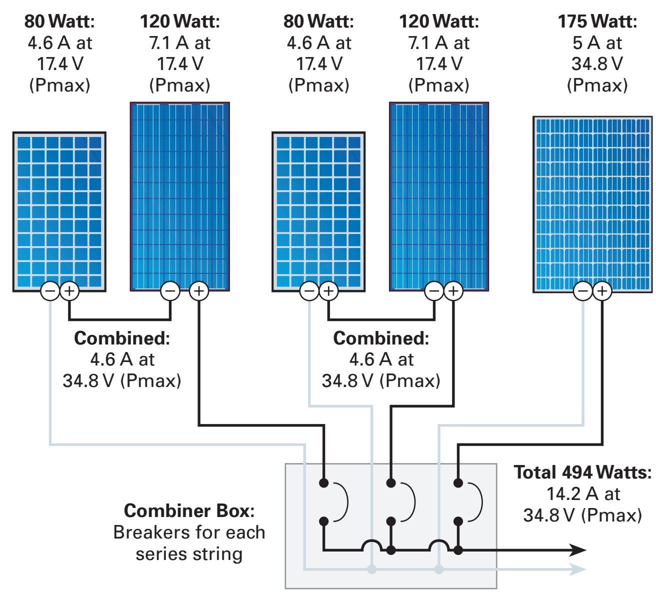


The power formula states that watts equals volts times amps. The 80-watt module has an Isc—the maximum current that a module can produce under standard test conditions—of 4.85 amps. You can measure short-circuit current with an ammeter, but only if the module is disconnected from any battery or load. When it's actually charging a battery, it produces about 95% of Isc; this is listed on the module's label as Imp, or "maximum power current," the current that the module puts out at a usable voltage. So the 80-watt module can generate about 4.6 amps at its maximum power voltage of about 17.4 volts.

Both the 80-watt and 120-watt modules are 12-volt nominal modules. Most modern modules designed for charging batteries are 24-volt nominal. The best way to wire the 12-volt modules will be to wire the two 80-watt modules in series and the two 120-watt modules in series. Bring both of these two-module strings into individual breakers in a combiner box at the array, and connect the 175-watt module to a third breaker. According to the numbers you supplied, your two 80-watt modules can produce about 4.6 amps, your 120-watt modules about 7.1 amps, and your 175-watt module about 5 amps, for a total of 16.7 amps at 24 volts nominal.

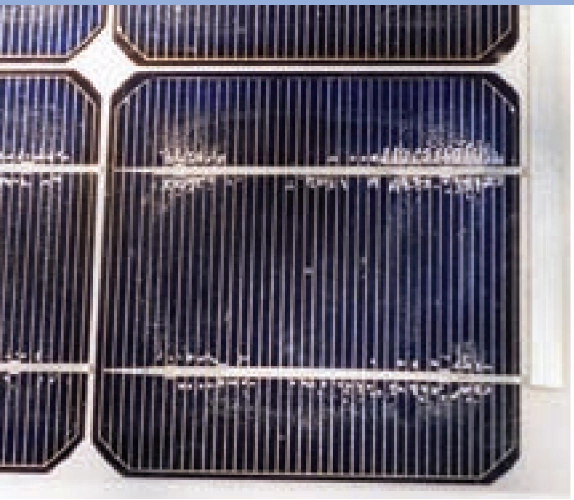
At 160 feet, you will need some pretty big wire to carry that charging current to the batteries. Using a standard charge controller, such as a Xantrex C40, you will need #1 copper conductors to keep your voltage drop under 3%. If you install a maximum power point tracking (MPPT) charge controller, you can use #2 conductors (one size smaller) and still stay under 3%. This is because the MPPT controller operates at the higher array maximum power voltage of about 34 volts; at the higher voltage, less current is lost to heat from wire resistance.

Bad: Dissimilar PVs in Series



Given the present cost of copper wire, reducing the wire size from #1 to #2 will save your customer about $150—savings that can go toward buying an MPPT charge controller. If you install even larger conductors to accommodate future array additions, the savings will be greater still. The charge controller upgrade will also put between 15% and 20% more usable power into the batteries in winter when it's most needed, but that's another subject.

Allan Sindelar, Positive Energy • Sante Fe, New Mexico



Damaged Modules?

I bought some Arco PV modules more than a decade ago and am finally using them again. They were stored in an unconditioned, screened shed and have little silvery extensions expanding off the thick silver lines in the middle of each cell. The modules are putting out a little less amperage compared to when they were new. What's happening?

Larry Behnke • High Springs, Florida

I also have some more than 20-year-old Arco modules on my roof that exhibit this phenomenon. Longtime solar user and advocate Larry Elliott says that the silvery extensions may be the growth of a crystalline lattice of tin oxide and silver oxide. "Combine oxygen and moisture," says Larry, "and the crystalline nature of tin and silver take over."

Christopher Freitas from OutBack Power reports having the same issue with some Siemens modules that were in storage for awhile. He says that this is caused by moisture on the solder joint of the ribbon to the cell, which encourages crystal growth from the combination of nickel on the interconnects, tin from the tin-oxide coating, and other residues from the flux used in soldering the cell interconnections. Freitas says that this is sometimes called "whiskering" when it happens on circuit boards. Once exposed to sunlight and heat, he reports that the whiskering on his modules diminished and the production returned to specified levels.

In my case, similar modules have been on my roof—not in storage—since the mid-1980s. But I do live in a moist environment, so perhaps that contributes to the problem. I have not unwired and tested the specific modules, but overall array performance has not suffered dramatically. I'll be interested to hear how your system performs over time.

Ian Woofenden • *Home Power*

What's the Law?

I saw the *National Electrical Code* mentioned in the John Wiles's article, "Code Changes through the Years" (*HP120*). Is this federal law? Are there other agencies that regulate at the federal level that I need to know about?

I live in Texas, so I assume that the state's Public Utility Commission would be the authority. Are other state agencies involved in regulating renewable energy systems? Or is regulation more common at the local level, with different rules depending on the county?

Jim Rush • Canyon, Texas

The U.S. *National Electrical Code (NEC)* is a more than 800-page document published every three years by the National Fire Protection Association. It is a set of guidelines developed over the last 110 years by a group of professionals in the various electrical industries, and covers nearly all wiring safety specifications in dwellings and other structures.

The *NEC* becomes legally mandated as the state legislators enact it and any local electrical codes into law. This happens at different times in different states. The *2008 NEC* is the current edition. However, California is still using the *2005 NEC*, and New York is still using the *1999 NEC*.

In Texas, the Public Utilities Commission governs utilities, but not the electrical systems in homes or commercial buildings. The Texas Department of Licensing and Regulation is about to replace the *2005 NEC* with the 2008 version. Typically, each state has an agency that oversees home electrical installations. Contact your state government—or search their Web site—for specifics in your case.

John Wiles,
Southwest Technology Development Institute •
Las Cruces, New Mexico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Vertical-Axis Wind Generators

I am confused. As a sustainable building developer and a longtime supporter of renewable energy, I applaud you for being a reliable source of information for laypeople. But I was surprised not to find a single vertical-axis generator listed in your article on "How to Buy a Wind-Electric System" (*HP122*). I also could not find any information on them in the usual wind-power reference books.

With most of my work centered in highly developed urban areas, I am limited in my use of horizontal-axis machines. Gaining acceptance of towers in the viewshed, dealing with turbulence caused by surrounding structures, and finding available space to put individual towers is a struggle. I am familiar with the limitations of old vertical-axis machine designs, but there are many new designs available. Increased airspeed due to rooftop effects should be advantageous in urban settings. The facts that these units can capture wind from any direction, pose less danger to birds, have lower mounting heights, and can be directly mounted on buildings effectively eliminate most of the arguments against using wind power in cities.

Is there something that I am missing about vertical-axis generators that makes them unacceptable for your publication or unsuitable for renewable energy generation?

Jeffrey Marlow • Huntingtown, Maryland


Courtesy Tammy Bryngelson

Horizontal-axis: still the state of the art.

You are not the only one confused. And you are correct that not a single vertical-axis turbine was reviewed in "How to Buy a Wind-Electric System," for very good reasons.

Both vertical-axis and horizontal-axis turbine designs were invented in the late 1920s, following the successful development of water-pumping windmills. Designers fiddled with several possible configurations in an attempt to extract more energy out of the wind for generating electricity. While there were many vertical axis configurations proposed, these could not compete with the efficiency, reliability, and economy of materials (and therefore labor) that came from the horizontal-axis turbines of the day.

During the late 1970s and 1980s, the U.S. Department of Energy funded lots of experimental wind turbine technologies, some of which were vertical-axis machines. Again, when it came down to cost of electricity as a result of efficiency, reliability, and economy of materials, verticals could not compete with horizontals. It all boils down to the marketplace—what works and what does not.

You bring up several other misunderstandings about vertical-axis machines that are prevalent in the public mind—that no tower is necessary and that vertical-axis turbines can be roof-mounted. Although these innovative clichés are all geared to make verticals seem like they are a breakthrough technology, these ideas ignore two major criteria of physics. First is that the friction near the Earth's surface between moving air masses and the ground significantly reduces wind speed—the quantity of the fuel that powers wind turbines. There is a reason that commercial wind turbines are mounted atop very tall towers, and it is not because wind farm operators do not want to kill the cows in the surrounding fields. Atop tall towers is where the fuel is. Second is that significant turbulence is created by buildings, trees, and the clutter that we humans put in our landscapes, compromising the quality of the wind. All the claims to the contrary made by vertical proponents are simply nonsense, as they ignore all we know about fluid dynamics and airflow.

Other claims are simply unsubstantiated or take advantage of the public's lack of knowledge on the subject. For example:

- Bird friendly. Where is the data that vertical-axis machines pose less danger to birds than small horizontal-axis machines?
- Can take wind from any direction. A horizontal-axis turbine can receive wind from any direction too. But turbulence is turbulence, which degrades the wind resource, regardless of the blade orientation.
- Endorsed by such-and-such celebrity. Do we even need to go there? Seek feedback from experienced wind energy users, installers, and consultants, not from those with money and celebrity status as their main qualifications.

When you're choosing a wind turbine, the most important information you'll need to know how many kilowatt-hours the turbine will generate at a certain wind speed. That one piece of critical information was missing from all the vertical-axis turbine Web sites I researched. If this critical data is not available for a particular machine, rule it out, regardless of configuration. The bottom line: If turbine designers do not provide this most important information, *Home Power* will not include them in future wind turbine guides. It's not about spinning; it's about generating renewable electricity.

Mick Sagrillo, Sagrillo Power & Light • Forestville, Wisconsin

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Mailbox

Courtesy Christine Olsen

Christine Olsen's "mini-mansion" in Bellingham, Washington.

Mini-Mansion

From my 800-square-foot dwelling in the northwest corner of Washington State, I am feeling compelled to write a response to the McMansion owner whose letter was printed in your *Mailbox* section in *HP121.* I think that, contrary to his belief, the writer *should* feel guilty about his McMansion. Living in Southern California does probably enable the local inhabitants to spend less on energy per square foot of living space, but many other factors exist that cannot be ignored.

First, there are many square feet in a McShelter. Consider the energy of lighting and other electrical loads in all those rooms, and the embodied energy of all the excess materials used to build and maintain these gargantuan abodes.

Also, although the writer is surrounded by nice, warm (albeit polluted) air, there is a dearth of water. If the Colorado River is sucked dry by rich northerners to water their large-home lawns, it will not reach those who need it farther south. Some brief information on water rights in California can be found at www.schoelles.com/Water/watermain.htm.

McMansions are by definition too-big houses on too-big lots. This leads to a dependency on cars and a loss of neighborly interaction, which people as social beings depend on. When large houses take over rural landscapes, farmers are pushed out of this sun-soaked land due to the high price of owning and leasing land.

Rather than spending money on his huge home, wouldn't it be better for the author to spend this excess income on real groups that work for positive environmental change? It may seem like a less-obvious gesture than donning a thick winter coat when the snow is falling, but he could also sell that SUV and turn the pool into a skate ramp.

Christine Olsen • Bellingham, Washington

Small is Beautiful

I really liked the articles on small-sized solar homes in the February/March issue. It was great seeing a family spending their hard-earned money on principled improvements instead of more square feet of house. I realize that the Solar Decathlon home competition was a demonstration of new ideas, and the home size was more a circumstance, but it still shows how much can be done in a small footprint. A previous article on Larry Schlussler's bungalow ("Extreme Efficiency—How Low Can You Go?" *HP112*) was also a hit for me—very aesthetic, functional, and unimposing.

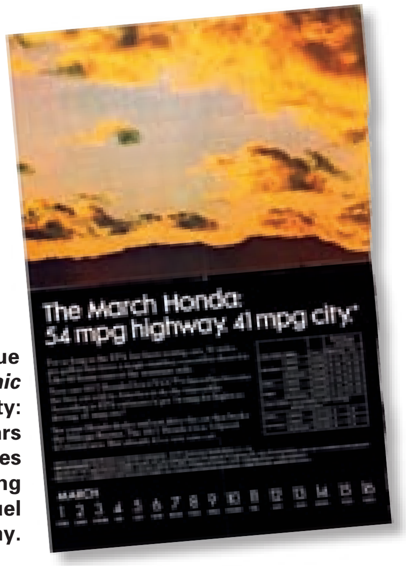
I've seen questions in *Home Power* asking how families with a modest income can possibly afford renewable energy systems. In addition to all the ideas given by *Home Power,* I would add that, if a family settled for half the square footage of house, they could buy an RE system with the savings. This smaller home could get by on a dramatically smaller system to heat, cool, and power it. Case in point is the relatively small (by American standards) solar-electric system recently profiled ("Bringing Solar Home: Small Changes, Big Results" *HP123*) that provides a comfortable 600-square-foot home with electricity to spare. They even ended up getting heated towel racks to utilize some of the extra solar energy!

There is an old backpacking principle—take only pictures, leave only footprints. When choosing a home, I would encourage people, especially people of modest means, to use this thought to counter the "big is beautiful" mantra. Live simply and leave as little of a footprint behind as possible.

Finally, I'm enclosing a page from a 1977 issue of *National Geographic* (pictured below). 54 mpg! 30 years ago. Today's engineers boast of 45 mpg with hybrids. What's wrong with this picture?

Cliff Millsapps • Garry, South Dakota

Here at *Home Power*, we all think small is pretty beautiful too. We just did some quick math and calculated the average home size for the fifteen households of the *Home Power* crew: 918 square feet. The winner? Our executive editor and CEO Joe Schwartz—his cabin is all of 216 square feet.



An ad in a 1977 issue of *National Geographic* points to today's reality: More than thirty years later, we still have miles to go in terms of achieving better vehicle fuel economy.

Courtesy Randy Richmond

EV Upgrade

Thanks so much for publishing the article about my 2001 GMC Sonoma EV conversion ("Born to be Wired," HP122). I have an update to my conversion story.

I found that my fears of exceeding the 400-amp battery current were unfounded. Canadian EV contacted me and suggested that I simply reprogram the Zilla controller for 550 battery amps. At that level, they felt there was no risk in overheating the battery terminals they supplied, and pointed out that my 500 A "fast-acting" fuse can tolerate several minutes of excess as long as it's by a relatively small amount. So I upped the amps, and now I keep up with traffic everywhere along my commute, even on the one steep hill.

Randy Richmond, RightHand Engineering • Woodinville, Washington

Union Discussion

I was very disappointed to read the article "Power Struggles" by Don Loweburg in *HP122*. It saddens me to see a member of the new class of green pioneers using many of the same anti-union arguments of the industrialists of yesteryear. By attacking the union's tactics, "greenmail," court cases, and legislation, Mr. Loweburg seems to not be opposed to the union's objectives of a living wage and democratic workplace for all solar installers, but his opposition to sharing the newfound wealth of the California solar gold rush is clear.

Can anyone imagine the author objecting to the use of these tactics to stop a new coal-fired power plant? And if it is not the tactics to which Mr. Loweburg really objects, it must be the goal of the unions. Perhaps it is just the involvement of the International Brotherhood of Electrical Workers that Mr. Loweburg objects to, and it is true that many old unions are not as democratic or responsive to their members as they should be. In that case, I am sure that Mr. Loweburg's next article will propose a model for incorporating the third pillar of sustainability—the social/democratic aspect—into California solar energies' successful implementation of the first two—environment and economic.

However, I doubt that is the case. If Mr. Loweburg seeks to "evolve...the business of investment in and construction of power-generating facilities," he should not be pushing for anti-union, pro-investor policies. Instead, he should be promoting more democratic practices that give equal power (not just electricity) to all the stakeholders, and equal return to those who have invested their labor and capital in a project.

Joe Rinehart, Appalachian State University • Boone, North Carolina

First, I think it's important to establish that I'm not reflexively anti-union. In fact, I have spoken with and interacted with IBEW folk at all levels, from lineworkers to union trainers. We have always had respectful and valuable exchanges. In several articles, I have also noted the IBEW's contributions in the areas of training and the implementation of PV on IBEW facilities and members' homes.

My attention was focused on the single union tactic of "greenmail"—specifically as applied to RE projects. I stand by my initial opinion that I do not think the IBEW should use this tactic on renewable projects that are inherently green. However, you are correct: I would not oppose the tactic when applied to a coal-fired power plant. To me, the distinction is obvious.

You are correct when you state that I do support the "union's objectives of a living wage and democratic workplace for all solar installers." I also support these objectives for non-union installers. However, I feel that the characterization of me (and the article) as "pushing for anti-union, pro-investor policies" is inaccurate.

As far as my "opposition to sharing the newfound wealth of the California solar gold rush," I would say this is your conclusion, not mine. My conclusion is that both the wealth and work must be shared. Further, disingenuous "greenmail" tactics will not be in the best interest of the IBEW.

Don Loweburg, Offline Independent Energy Systems • North Fork, California

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Wire Color Code

I just read through the "Deciphering Schematics" article in *HP123*. With respect to wiring, I think it's great that someone is taking the initiative to bridge the gap that has existed between automotive and the rest of the electrical world. This has been a point of confusion for a lot of people for a long time. I would like to bring up one point for discussion. For DC systems, *Home Power* selected black as the positive (ungrounded) and white as the negative (grounded) wire color. I've been pondering this color-coding issue for some time and have started using red for the ungrounded conductor and white for the grounded conductor in the DC portion of the system. And here is my reasoning.

In the AC world, the *NEC* is quite clear on color coding for equipment-grounding conductors—bare or green in some form or combination. For grounded circuit conductors, white or gray in some form is used. With respect to the *ungrounded* conductors, though, I am not aware of anything in the *NEC* that specifies color coding so specifically, except that they cannot be green or white. Convention uses black as the ungrounded for 120 VAC, and black and red for the ungrounded for 120/240 VAC. I agree wholeheartedly with continuing the white for the grounded conductor, and bare or green for the grounding. The *Code* is very clear on those conductors, and this requirement should carry through to the DC world.

However, I prefer red (instead of black) for the DC ungrounded conductor. Red is the traditional automotive ungrounded color. If we switch to black for the ungrounded, we will then have DC systems

I think it's great that someone is taking the initiative to bridge the gap that has existed between automotive and the rest of the electrical world.

where the black could represent either the grounded or the ungrounded. If red is kept as the ungrounded color, the only change is black to white for the grounded—less confusing. Also, 120 VAC wiring is going to have a black-white-green wire set. In AC systems, red does not appear until 240 V, in which case there are usually four conductors. So a DC red-white-green conductor set would then be differentiated from the 120 VAC set.

I have one additional point. The DC colors are tied to positive and negative in the article. To stay consistent with *NEC*, they should be identified with the ungrounded and grounded portions of the DC circuit. In the majority of the DC systems, the negative is the grounded side, but not always.

Jim Norman, ABS Alaska • Anchorage, Alaska

Instructor Carol Weis from Solar Energy International had similar comments in response to "Deciphering Schematics" in *HP123*, and both of you make some very good points. Referring to conductors as "grounded" or "ungrounded" rather than negative and positive is better usage since these terms are consistent with the *NEC.*

The only specific requirements that the *NEC* makes regarding wire color codes is the proper way to identify equipment-grounding conductors and grounded conductors, as you mention above. In terms of the *NEC,* ungrounded conductors can be any color. In the field, black and red are the most common ungrounded wire identification colors. We feel that either a black or red conductor color for the ungrounded DC conductor is appropriate. Electricians will readily recognize both as ungrounded conductors.

Joe Schwartz • *Home Power*

Referring to conductors as "grounded" or "ungrounded" rather than negative and positive is better usage since these terms are consistent with the NEC.

Collector Categorization

In *Home Power's* 2008 Solar Thermal Collector Guide ("Get into Hot Water," *HP123*), we had some difficulty categorizing one collector. The Solargenix collector is neither a flat-plate nor an evacuated-tube collector, but a parabolic collector. You'll find more information at the company's new Web site: www.solargenixchicago.com.

To send a letter to
***Home Power's* Mailbox,**
write to: **mailbox@homepower.com**
or **Mailbox, c/o Home Power**
PO Box 520, Ashland, OR 97520

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.

Shifting into Action

Solar-Powered Home & Car

by Benjamin Root

Kathleen Root doesn't consider herself an activist. Sure, she has ideas and opinions about politics, the environment, and the economy. She cares about her future, the future of her children and soon-to-be grandchildren, and everyone on the planet. But she's not the type to stand on a soapbox and preach. So why would she invest her hard-earned dollars on expensive technologies like a photovoltaic system and an electric car?

Josh Root (2)

When cornered, Kathleen will admit her opinions on the environment, energy politics, and social responsibility. And since the installation of her photovoltaic system, she's become a member of a local climate-change awareness group that has spearheaded projects like bike racks for downtown and "no-idle" zones in school turnarounds. But she's quick to remind that it's not to prove a political point, make an environmental statement, or convince anyone else how they "should" live. "It's my responsibility to acknowledge my own energy use and impact, and do what I can," says Kathleen. "I have the resources to do these things, so I'm doing them. Other people have different resources and must make their own decisions about what they can and should do."

Getting Motivated

Kathleen blames it all on her silver station wagon. Her Audi A4 looks like a placid soccer-mom's car. But with 217 horsepower under the hood, it would have blown the doors off the muscle cars her sons coveted in their youth. Although Kathleen wasn't drag racing down the streets in her hometown of Anacortes, Washington, she was still getting pathetic fuel economy—sometimes as low as 14 mpg. When she complained about the wagon's around-town mileage to the dealer, he quizzed her on her driving practices. It turned out that Kathleen's short trips to work, the post office, and the grocery store—all less than a couple of miles from her doorstep—were not only wasting fuel, but wasting the car—and lots of her hard-earned money.

But what were her alternatives? Fifty-eight-year-old Kathleen is healthy and active—she's fit enough that walking or riding her bike are options. But western Washington's notoriously chilly, wet weather isn't conducive to keeping her clothes neat and dry, necessary for her professional work as a middle-school counselor. What she wanted was an around-town vehicle that could keep her warm and dry—and sip, not guzzle, fuel. And then she found her Zenn.

The west-facing, 1,560-watt Sanyo array.

Enlightened Mobility

Kathleen is a pretty typical American, but what frequently sets her apart is her willingness to give cutting-edge technologies a whirl. (You can blame that—at least in part—on her technophile sons, one of whom has been working with renewable energy for more than a decade.) So it wasn't surprising when she found the Zenn—"Zero Emission, No Noise"—neighborhood electric vehicle.

With a top speed of 25 mph, a range of up to 35 miles per charge, and plenty of space for groceries in its hatchback, the Zenn is well-suited for the short trips that are typical for Kathleen. At 3 miles per KWH (about 135 mpg equivalent), the car is inexpensive to drive, costing only $0.024 per mile. Besides fuel savings, electric vehicles like the Zenn also eliminate the regular replacement and repair costs of oil changes, oil filters, exhaust system fixes, and tune-ups associated with internal combustion engines. Slower driving speeds and regenerative braking, which uses the motor to slow the vehicle and recharge the batteries, also mean reduced brake wear. To Kathleen, the Zenn's $13,000 sticker price was a reasonable cost to pay for a reliable ride that would deliver her, warm and dry, to her destination, as well as extend the life of her Audi, which she saves for road trips.

From the alley: Kathleen's traditional home sports twenty-first-century technology.

Zenn Tech Specs

Body type: Three-door hatchback; automotive aluminum alloy frame

Propulsion: 100% electric, front-wheel drive

Charging: Standard 120 VAC outlet; 80% recharge in 4 hours, complete charge in approximately 8 hours

Wheel base: 81.8 in.

Curb weight: Approximately 1,200 lbs.

Gross vehicle weight rating: 1,705 lbs.

Track: Front and rear—49.8 in.

Storage: 13 ft.^{3}

Range: Up to 35 miles

Speed: 25 mph; limited in accordance with FMVSS 500 regulations

Brakes: Dual hydraulic system, four-wheel disk, with electromagnetic regeneration

Batteries: Six, 12-volt heavy-duty, sealed lead-acid

Base price: $12,750

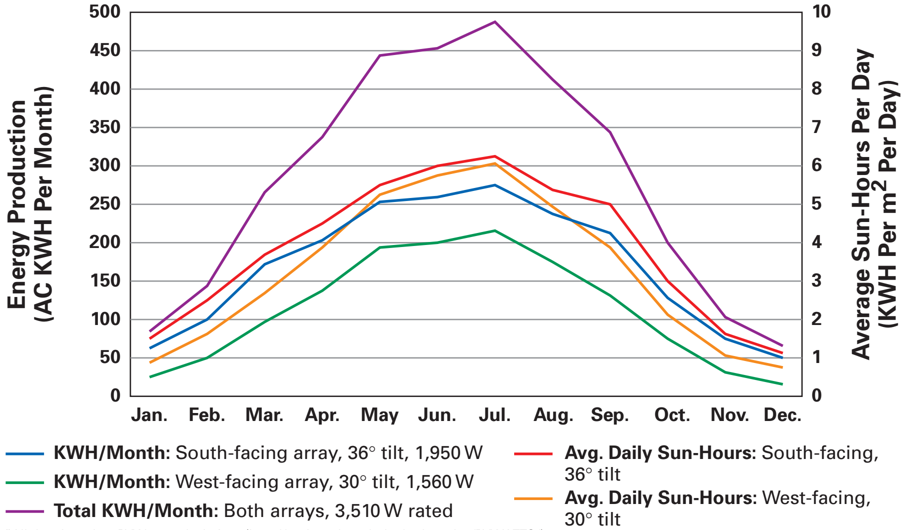
The car's six 12-volt sealed lead-acid batteries supply electricity to the motor, and charging is a breeze—the Zenn's recharging dock is compatible with any typical 120 VAC household outlet. A complete charge takes about eight hours, and batteries can be 80% recharged in four hours. Kathleen simply parks her car in the driveway and plugs it into an exterior outlet every night for easy charging.

"I wanted a car that had room for another passenger, ample head and leg room, and cargo space to haul groceries and 50 pounds of dog food. I also wanted something that looked like a real car—not a glorified golf cart," says Kathleen. But the biggest benefit, she says: "I can generate my own pollution-free fuel."

Kathleen admits that there are a few drawbacks to driving such a unique vehicle. "It turns you into a bit of a celebrity. Little kids wave, people stare and point, everyone wants to ask you questions about it," she says. Kathleen estimates that in the first few months of owning the Zenn, she talked with hundreds of people. "I even had a very excited man follow me into my driveway to ask me about the car." Kathleen acknowledges that some people are disappointed when they find out the Zenn's top speed and range. "What most people really need are plug-in hybrids," she says. But she's patient and usually willing to share information about her EV. And when she's not in the mood for providing electric-vehicle education? "I go to the grocery store at night," she says.

Little did Kathleen expect that her sage-green Zenn would take her even further down the renewable-energy road. She was already aware of the concept of photovoltaic (PV) modules generating a home's electricity, but when it was suggested that a solar-electric system could power her car, she got really excited about the technology. "The idea that I could drive my car with energy from the sun was irresistible to me," she says.

Projected Performance & Average Sun-Hours



*All data based on PVWatts calculations (http://rredc.nrel.gov/solar/codes_algs/PVWATTS/)

On the RE Road

There are a few ways to size a photovoltaic system. In off-grid situations, the system is necessarily sized to meet all the loads on a sunny day. Typically, a small amount of backup generator time is factored in to alleviate the excessive costs that would otherwise be required to provide for total loads during extended cloudy periods. But system sizing is significantly more flexible for grid-tied systems, since utility electricity is available to make up the difference between PV production and load requirements. Usually, sizing a grid-tied system becomes a balance between budget and available mounting area for PV modules. In Kathleen's case, the roof area of her 2,000-square-foot, two-story home was the limiting factor in sizing the PV array. It was decided to squeeze as much generating capacity onto the roof as was functionally and aesthetically reasonable.

The 1,950-watt, south-facing array with the San Juan Islands in the background.

Open for inspection: Two Fronius IG 2000 inverters (one for each array), the DC array disconnect, and a handy wiring "gutter."

While peak sun-hours in the area can dip below 1 per day in December and January, the summer months of June and July make up for it to contribute to an overall daily average of about 3.7 peak sun-hours. At 48 degrees north latitude, Anacortes experiences the most sunshine and highest peak sun-hours during summertime, when the sun traces a long arc through the sky, rising in the northeast and setting in the northwest. Kathleen's grid-tied PV system would rely on these long, sunny summer days to heavily weight its net solar production for the year. To maximize PV generation capacity, it was determined that, along with a south-facing array, a west-facing array would contribute significantly to the system's total energy production. The idea of installing an east-facing array was rejected due to shading from trees and neighboring buildings. Plus, in this coastal town, morning fog can reduce solar insolation—even in the summer months.

Choosing Equipment

With maximizing the PV array output as the goal and roof area as the limiting factor, high-efficiency Sanyo HIP-195BA3 PV modules were selected. These 195-watt modules fit in two rows of five on the south-facing roof and two rows of four on the west-facing roof. The dimensions of other PV modules that were considered didn't work well with the available roof space in portrait format, or would have required additional racking and mounting hassle in landscape format. (Savvy PV shoppers will recognize that the Sanyo HIP modules also come in 200- and 205-watt ratings with the same overall dimensions. However, at the time, these higher-rated modules were difficult to obtain.)

Tech Specs

Overview

System type: Batteryless, grid-tie solar-electric

Location: Anacortes, Washington

Solar resource: 3.7 average daily peak sun-hours

Average monthly production: 278 AC KWH

Utility electricity offset annually: 32%

Components

Modules: 18 Sanyo HIP-195BA3, 195 W STC, 55.3 Vmp

Array: Two, five-module series strings, 1,950 W STC total, 276.5 Vmp (south-facing array); two, four-module series strings, 1,560 W STC total, 221.2 Vmp (west-facing array); 3,510 W total

Array combiner boxes: Two GroSolar

Array installation: Direct Power & Water Power Rail mounts, 36-degree tilt (south-facing roof) and 30-degree tilt (west-facing roof)

Inverters: Two Fronius IG 2000, 500 VDC maximum input voltage, 150–450 VDC MPPT operating range, 240 VAC output

System performance metering: Fronius IG Personal Display and production KWH meter

The other major equipment choice was the grid-tied inverters that would convert Kathleen's solar-generated DC electricity into AC electricity. In turn, this renewable electricity would be used to power household appliances and charge the Zenn, with any excess sent to the utility grid. While there are several reputable manufacturers of grid-synchronous inverters in the market these days, two Fronius IG 2000 units were deemed a good fit. The west- and south-facing arrays would have different numbers of modules and different voltages at maximum power—221.2 and 276.5 volts, respectively. As such, one inverter would not have dealt optimally with these mismatched input voltages. Instead, two 2,000-watt inverters were installed side by side (one for each array) and paralleled on the AC output side.

The Photovoltaic Effect

Although Kathleen wasn't a complete stranger to smart electricity use before installing a PV system, once her Fronius remote meter was spitting out the daily totals for energy production, conservation became her new hobby. Even during the winter, when a day's total PV output can be less than 1 KWH, her new habits are making a noticeable impact.

Besides programming temperature setbacks to regulate her home heating, Kathleen has taken to drying clothes on a rack in the laundry room instead of in the dryer. "It only takes a couple of minutes to hang them up and they're dry in a day. This is not really about sacrifice: I still throw my towels in the electric dryer because I like them soft. Instead, it's about what we can do relatively painlessly that has a positive impact." And those positive impacts are paying off. Kathleen's December electricity usage was 25% lower than in 2006—even with the additional load of charging the Zenn. And that's not even counting production from the PV system.

Rooftop to Ground

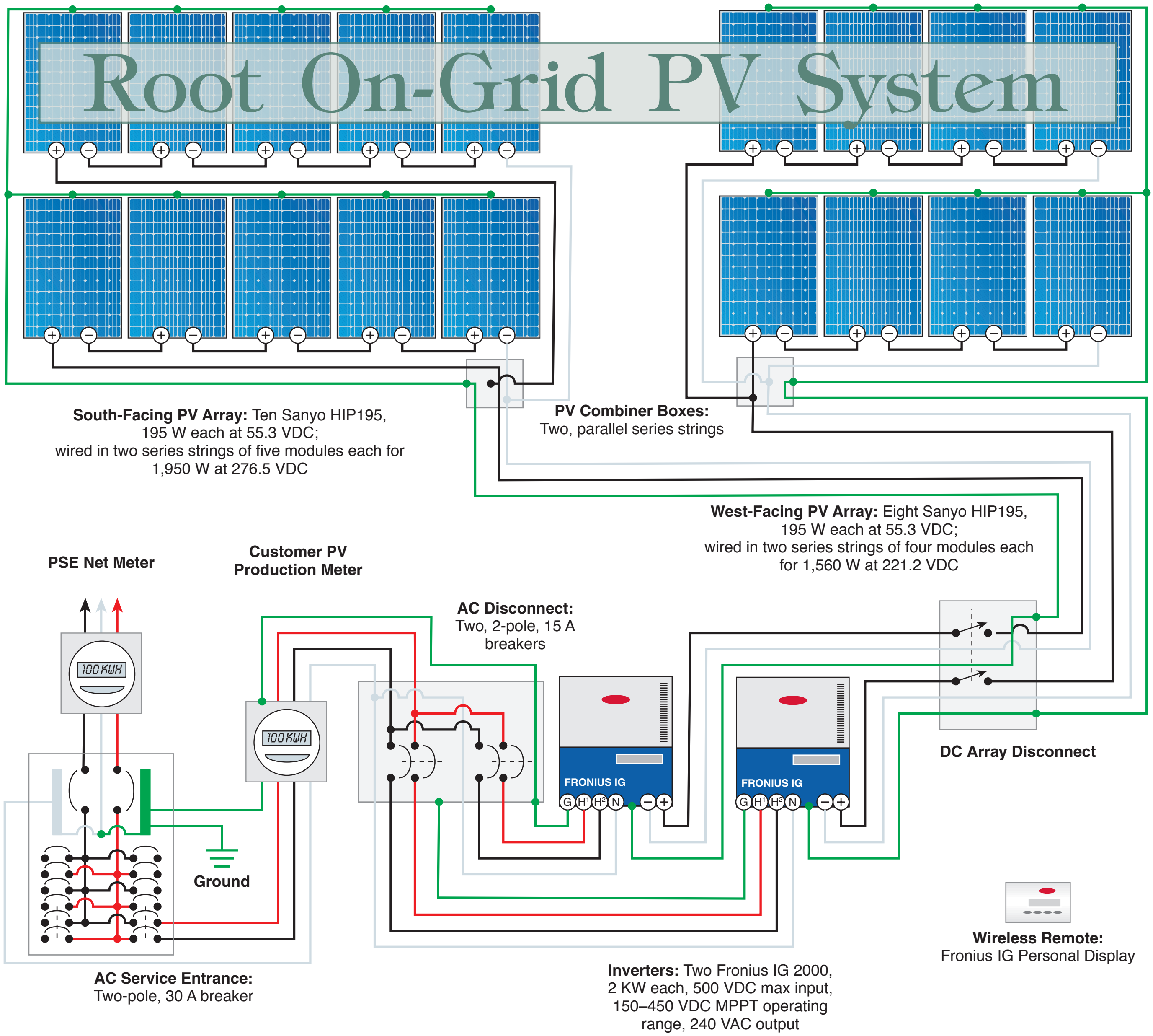
On the south-facing rooftop, the PV modules are mounted on Direct Power & Water Power Rail mounts and wired in two series strings of five modules each. The two strings are wired in parallel in a combiner box mounted to the roof. The west-facing array of eight modules is mounted and wired similarly, but the series strings contain only four modules each. Six-gauge, bare, stranded copper wire was used between the modules for equipment grounding. The equipment-grounding conductors were transitioned to 10 AWG in the combiner boxes.

A single conduit run carries a pair of #10 conductors, plus the #10 equipment ground wire, from each array through the roof overhang and down to the balance-of-system components mounted on the house's exterior. The positive wire from each array passes through the DC disconnect switch before the pairs terminate at the two Fronius inverters. One inverter processes 1,950 watts (Pmax) at 276.5 volts from the south-facing array, and the other processes 1,560 watts (Pmax) at 221.2 volts from the west-facing array.

On their output side, each inverter produces 240 VAC. A quartet of wires exits each inverter—two hots, a neutral, and an equipment ground. The four hot wires pass through two, two-pole, 15-amp breakers that act as the main AC disconnects and overcurrent protection for the PV system. On the line side of these breakers, the four hots are paralleled into a single pair of hot wires and join one neutral wire for the journey to the production meter.

The production KWH meter is an additional component. In many grid-tied PV systems, a single, bidirectional KWH meter measures net production from the PV system as well as electricity consumption from the grid. In Kathleen's case, her utility meter doesn't deduct the PV-produced electricity from her utility electricity purchase. Instead, the designated production meter keeps track of the electricity produced by the PV system, which she is paid for. (See the "The Performance Connection" sidebar on page 32 for more information on how Kathleen's system pays her back.)

From the production KWH meter, the two hot wires, a neutral wire, and an equipment-ground wire continue to the AC service entrance. The hots enter a standard household AC distribution panel through a two-pole, 30-amp, 240 VAC breaker. There, the neutral and ground wires terminate at their respective bus bars. The energy produced by Kathleen's PV system either contributes to the mix of electricity powering her household loads or, if the system is producing more electricity than she's using, enters the electric utility grid through her utility KWH meter.



While Kathleen didn't actually climb on her roof to install her PV system, she was definitely involved with the planning and paperwork of the process, especially the permitting and net metering agreements. "I was amazed and inspired," she says, "with how patient and helpful everyone was." Skagit County Head Electrical Inspector Dennis Patterson readily answered technical questions in advance. Jake Wade, program implementer of the Renewable Energy Advantage Program at Puget Sound Energy (PSE), Kathleen's electrical utility, walked her through all the necessary paperwork to get her system signed up for production

A wireless remote meter helps Kathleen keep tabs on her PV system's production.

The Performance Connection

Of the more than 40 states that offer some sort of incentive for utility-tied renewable energy systems, Washington is one of only a handful that provides performance-based incentives (PBIs). While other states or utilities that offer PV incentives typically provide a one-time rebate based on a PV system's rated watts (capacity-based), Washington provides payment, though the utility, for the electricity actually produced by the system. Under the PBI scenario, payment is for every KWH that the system produces, whether it is actually fed to the utility grid or used immediately in the system owner's home. Most other net metering agreements often involve simply offsetting either monthly or annual electricity use with RE generated electricity. Any excess energy that those systems produce is either sold to the utility at retail rate, avoided generating cost (a fraction of the retail rate), or sometimes nothing at all (the system owner "donates" the excess electricity to the utility).

Although Kathleen received no incentive money up-front from the state to help her pay for her system, under the PBI program, for at least the next seven years, she will receive $0.15 for every KWH her system produces (about twice the utility retail rate). Based on her system's projected performance, it could earn $3,500 in those seven years. If these PBIs are renewed, Kathleen could expect $15,000 over the system's assumed 30-year life.

If she is using that PV-produced energy herself, then she's also offsetting the cost of utility-based electricity. In essence, when she's using her solar-generated electricity, Kathleen's PV system is paying for itself at a rate of about $0.22 per KWH. As the price of electricity goes up, the value of her own PV-produced offset goes up too.

In the future, it's possible that more states will transition to PBI incentive structures, rewarding system owners for their system's actual output, rather than just their rated potential. This means that more care will be taken to ensure proper system design and installation and more attention paid to properly maintaining the system's level of performance over its lifetime.

The PV production meter next to the system's AC disconnect.

Root PV System Costs

Item	Cost
18 Sanyo HIP-195BA3 photovoltaic modules	$19,800
2 Fronius IG2000 grid-synchronous inverters	3,200
Direct Power & Water Power Rail PV mounts	1,600
Miscellaneous wire, conduit, etc.	894
Shipping	795
Fronius Personal Display, 2 wireless cards	546
2 GroSolar PV combiner boxes	170
Square D DC disconnect	165
PSE net KWH meter	165
4 MC home run cables, 50 ft.	140
Square D AC disconnect, 30 A	80
WA state electrical permit	64
KWH meter base	50
PV production KWH meter	0
Labor (donated)	0
Total Costs	$27,669

Rebates & Credits	
PSE rebate	$-2,018
Federal tax credit	-2,000
Residential energy tax credit	-500
Total Credits	$-4,518
Net Cost	$23,151

incentives. "His repeated friendliness and willingness to meet me on my technical level was above and beyond the call," says Kathleen. Even the two PSE meter installers, who came to commission the system, helped fix a wiring oversight rather than reschedule the inspection. "Though there was a lot to learn, these guys all helped make the switch to state-of-the-art green energy pretty painless," says Kathleen.

So, no, Kathleen Root doesn't consider herself an activist. Her goal is not to tell you why solar energy is better than coal or nuclear energy—or why an electric car is better than a gas guzzler. She is not going to tell you how you should live: Her goal is to take some responsibility for how *she* lives, and have that responsibility be in proportion to her means. She has chosen not activism, but action.

Access

Benjamin Root (ben.root@homepower.com) has been a graphic designer with *Home Power* for more than 12 years, and has been the art director since Publisher Richard Perez started giving out titles. Kathleen Root is Ben's stepmother, and Ben was the primary system designer on her project.

Manufacturers:

Direct Power & Water • www.directpower.com • Rail mounts

Fronius • www.fronius-usa.com • Inverters

Sanyo • www.us.sanyo.com • PVs

Zenn Motor Co. • www.zenncars.com

Anatomy

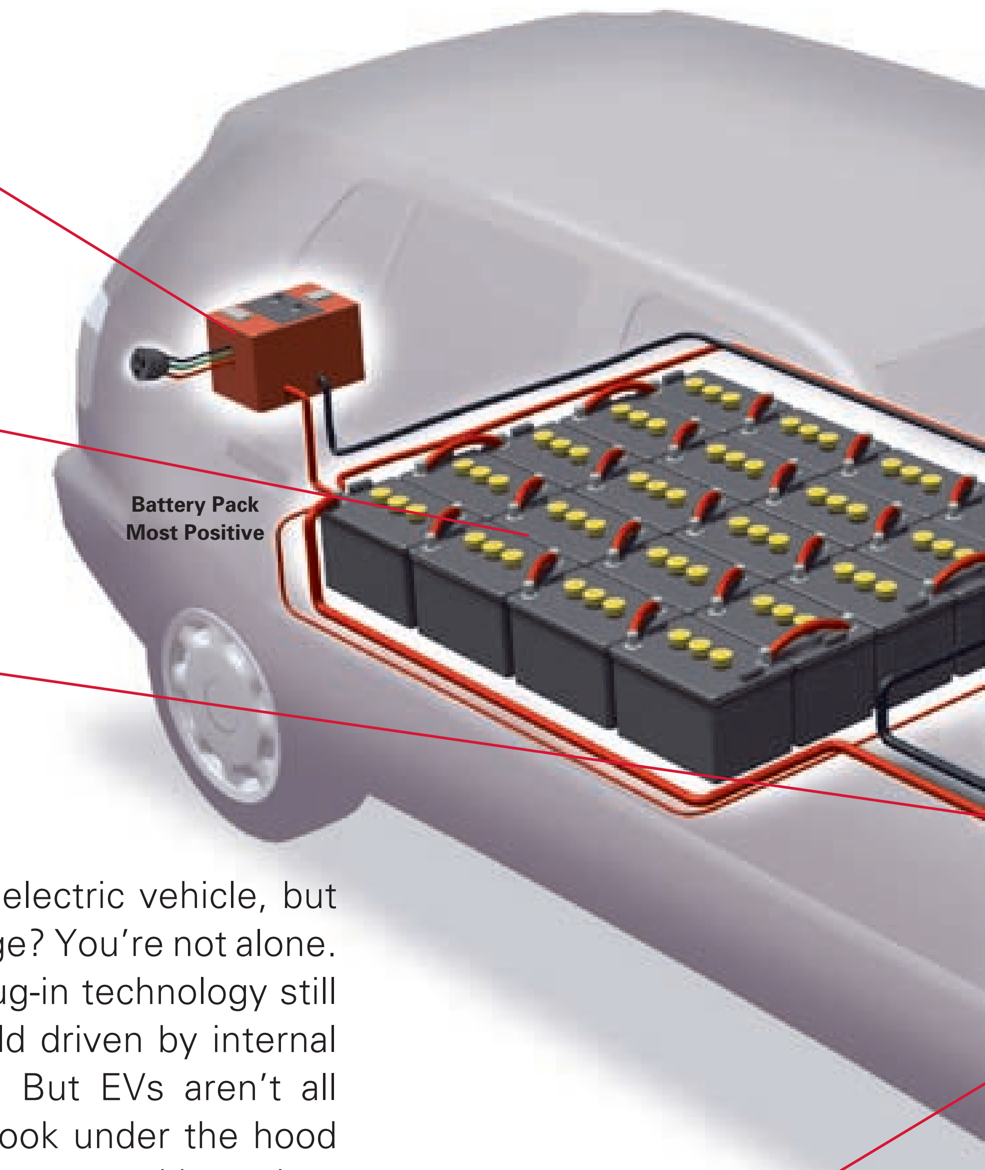
by Shari Prange

1. Charger

Plugged into a standard 120 or 240 VAC household outlet, the charger converts alternating current to direct current to charge the traction batteries.

2. Batteries

Sealed or vented, and in an array of possible voltages, the battery bank provides the "fuel"—and fuel storage—for the vehicle.



3. Controller

The brains of the EV, the controller adjusts the amount of energy sent to the motor based on signal input from the throttle potbox.

Sold on the idea of an electric vehicle, but afraid to take the plunge? You're not alone. For most of us, EV plug-in technology still remains a mystery in a world driven by internal combustion engines (ICEs). But EVs aren't all that complicated. Here's a look under the hood to show you an EV's components and how they work together to get you from here to there. We'll follow the path of the energy, from its source as electrical energy to its final application as mechanical energy at the drive wheels.

6. Transmission

Mounted to the electric motor the same way it would mount to a gasoline engine, the gearbox transfers power and torque to the drive wheels.

# of an EV

7. Main Contactor

The EV's main on/off control, this relay is often governed by a standard key switch.

8. Instrumentation

The right meters are imperative to keeping tabs on your EV's performance. Standard are a voltmeter, ammeter, and, sometimes, an amp-hour meter.

9. Emergency Disconnect

This emergency breaker/switch automatically disconnects the battery bank in the unlikely event of a short circuit. The switch can also be used to manually disconnect the battery bank.

10. DC/DC Converter

Converts traction battery pack voltage to standard 12 VDC to run common automotive electrical accessories.

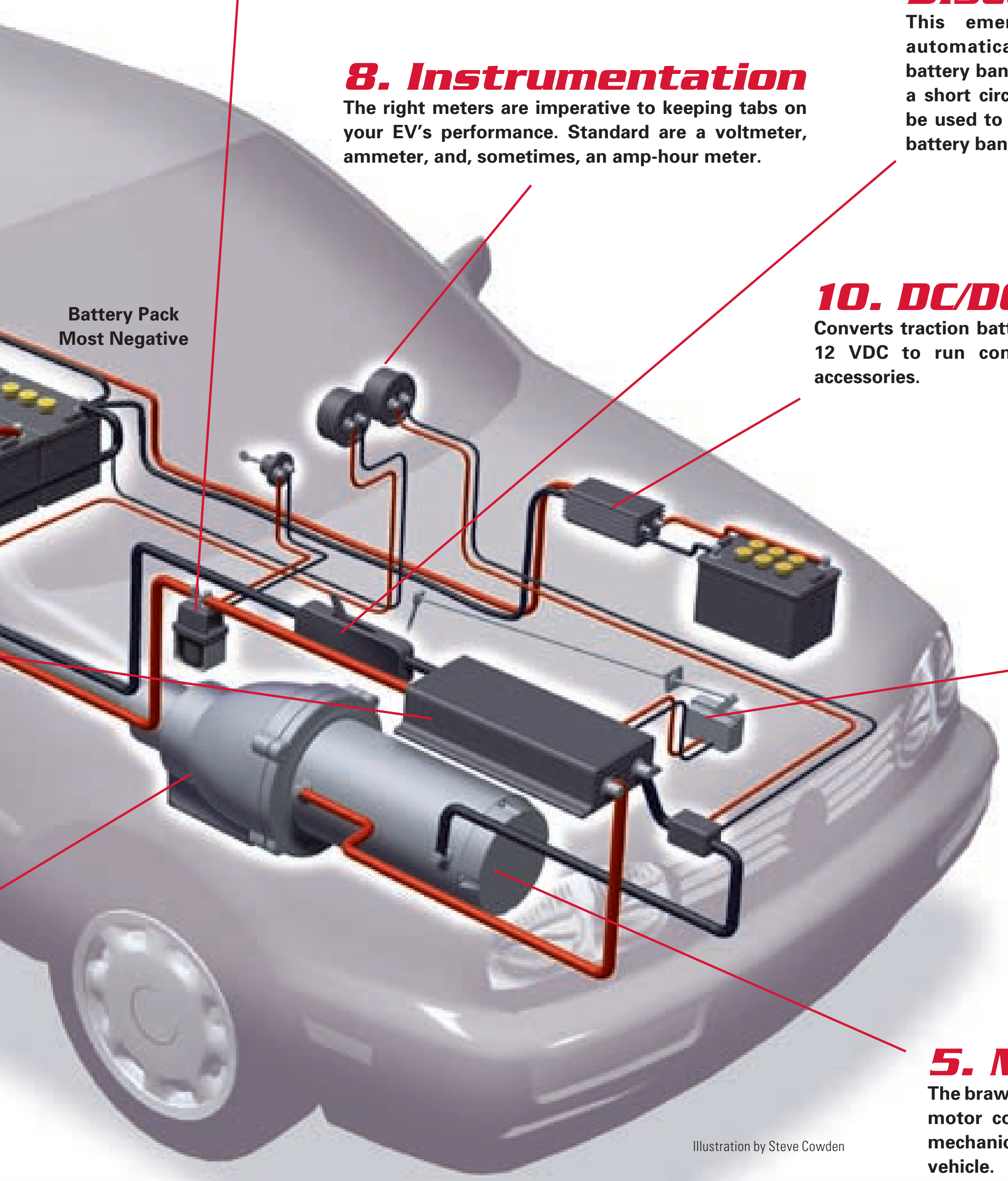


Illustration by Steve Cowden

4. Potbox

Converts the motion of your throttle pedal into an electrical signal for the controller.

5. Motor

The brawn of the EV, a DC or AC electric motor converts electrical energy into mechanical energy, which moves the vehicle.

1. Charger

Once programmed with a charging profile that matches your electric vehicle's battery pack (which provides the "fuel"), a charger brings the alternating current (AC) from the grid or an RE system into the vehicle, and converts (or "rectifies") it into direct current (DC) to charge the batteries. Depending on the model, a charger may either automatically shut off when the batteries are fully charged, or drop to a low-current finish charge and hold there. The type of charger you use is a matter of preference, but if the car will sit idle for a day or more, you might want the auto shutoff feature. This way, you don't have to worry about overcharging the EV's batteries or wasting energy.

The majority of chargers accept 120 VAC input from a standard household outlet. Other chargers require input from a 240 VAC receptacle (such as a clothes dryer outlet) to more closely match the higher voltage of the vehicle's battery packs. Though 240 VAC outlets are harder to find when you're away from home, they provide a faster charge than 120 VAC outlets. A typical EV battery pack, if completely drained down to 20% of full, takes about 8 to 12 hours from 120 VAC to be fully recharged—versus 4 to 6 hours from 240 VAC. The higher voltage input to the charger makes the higher charging current possible.

Be sure to match the charger to the battery pack. Charging too quickly can damage some battery types, and charging too slowly can damage others. A few chargers accept both 120 and 240 VAC input, but these dual-duty chargers are larger and more expensive than single-input models. For charging flexibility, a 120 VAC charger can be kept onboard for opportunity charging and a 240 VAC charger can be used at home for faster charging.

2. Batteries

From the charger, electricity flows to the battery pack through its positive and negative terminals. In the battery, DC energy is stored by a chemical reaction. An electric load (in this case, the EV's motor) connected to the battery posts causes the chemical reaction to reverse, releasing energy to the load.

A battery's suitability largely depends on several factors in its design—including the number of plates and their thickness, the ratio of plate material to electrolyte, and the shape of the plate. The most common batteries in EVs are lead acid, nickel metal hydride, or lithium ion. Batteries in EV conversions can be sealed or flooded, and are typically lead acid. Flooded batteries need to have water added periodically. The sealed batteries generally found in factory-built EVs do not require maintenance.

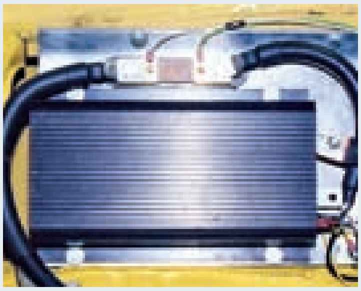
An EV's batteries are wired in series, which means a daisy chain of connections from the positive post on one battery to the negative post of the next. This type of wiring adds the voltage of the individual batteries to build up a higher voltage pack. Battery-pack voltage can be as low as 36 V to 72 V for neighborhood electric vehicles (NEVs), or from 96 V to more than 300 V for a full-function, highway-capable EV.

Courtesy Randy Richmond

3. Controller

An EV's speed controller is the equivalent of the carburetor or fuel-injection system in an ICE vehicle. To control the vehicle's speed, the controller takes the energy from the battery pack and feeds it to the motor in a regulated manner. Modern controllers do this by pulse-width modulation, taking the full voltage from the battery pack and feeding it to the motor in thousands of tiny on–off pulses per second. The longer the duration, or "width" of the "on" pulses, the more electricity the motor receives and the faster the vehicle moves. Because the pulses are so tiny, the process feels completely smooth to the driver.

EVs can have AC motors or DC motors, and each needs its own kind of controller. In EVs with AC motors, an AC controller must first convert the DC from the batteries into AC before feeding it to the motor.



4. Potbox

How does the controller know how much energy to give the motor? The potbox tells it. This linear potentiometer is a sensor that produces a resistance output proportional to its displacement or position. It responds to the driver's foot pressure on the throttle pedal and sends a corresponding signal to the controller. The throttle pedal in an EV works just as it does in an ICE vehicle—the more you depress it, the faster you go.

5. Motor

The motor is the brawn of the EV, converting electrical energy from the batteries into mechanical energy to propel the vehicle. Instead of invisible electrons flowing through wires, we now have rotating components.

It's the relationship between electricity and magnetism that enables the motor to do work. Passing electricity through a wire creates a magnetic field around the wire. By winding wire in a motor and running electricity through it, magnetic poles that repel each other are created, causing the shaft of the motor to spin.

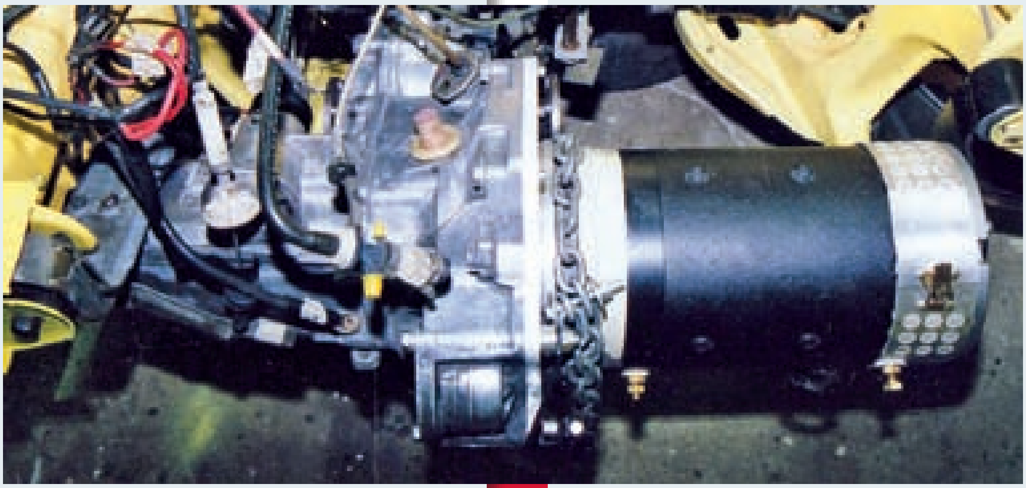
If the EV has regenerative braking, the motor can also act as a generator. When the vehicle is coasting or braking, the momentum of the car drives the motor—rather than the motor driving the car. The magnetic fields induce current in the wires, the flip side of the process described above. The electricity flows backward through the controller (which rectifies it from AC back into DC) and into the battery pack. This process also creates drag on the motor—the "braking" part of regenerative braking, which is very similar to what happens in an ICE car when you lift your foot off the throttle in a low gear. Though it's an intrinsic part of AC drive systems, regenerative braking is more rare in DC systems, where a special controller and extra wiring are required to allow the motor to serve as a generator.

6. Transmission

The energy output from the spinning shaft of the motor now needs to reach the drive wheels. On a very small EV, the motor might drive the wheels directly, but with full-size vehicles, at least one level of gear reduction is necessary to reduce the revolutions per minute (rpm) of the motor to a usable speed at the wheels. A "direct-drive" vehicle will have a single gear reduction, which might be a gearbox or a belt-and-pulley arrangement. No shifting is necessary. This is common with AC motors that have upper limits of 8,000 to 13,000 rpm. DC motors with limits of about 5,000 to 6,000 rpm usually use the same kind of multiple-gear manual transmissions found in ICE cars. In EVs with manual transmissions, the clutch is usually retained and works the same as in an ICE vehicle.

The electric motor is connected to the vehicle's original factory transmission by means of an adaptor plate and hub. The plate (and usually a spacer ring) physically attaches the motor to the transmission and precisely aligns the shaft of each with the other. The hub mounts to the motor's drive shaft and transmits the power to the transmission drive shaft.

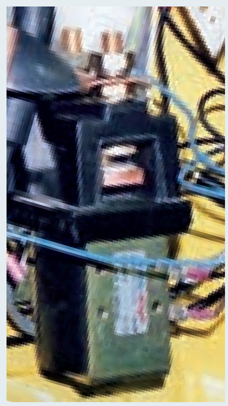
From the transmission, gearbox, or pulley, the power goes to the drive wheels in the same way it does in an ICE car: through a differential, a device that splits the engine torque and allows the wheels to spin at different speeds on corners, and then through the axles to the wheels.



The motor and transmission, mounted in the engine compartment.

7. Main Contactor

When you turn the key in an EV, nothing seems to happen. You don't hear the engine turn over and catch. What does happen—silently—is that electricity flows from the battery pack to this contactor, which serves as a gateway to the speed controller. The car is now ready to roll. When your foot depresses the throttle pedal, the contactor closes, allowing the electricity to flow to the speed controller. While the potbox tells the controller how much electricity should go to the motor, the actual power flows through the contactor, once it closes and makes the connection.



Better Batteries with BMS

Individual batteries, even of the same model, can have slight variations in performance. Over time, the charge levels of the batteries can grow more disparate, with the result that some batteries may take longer to charge than others. This imbalance will eventually damage the batteries and greatly shorten their cycle life, as some batteries get overcharged while others lag behind.

In an EV, a battery management system (BMS) monitors the charge level for each battery in your battery pack. The BMS consists of a network of small regulator units, one on each battery. When a particular battery is fully charged, the regulator cuts off the battery from the charging circuit and bypasses it, preventing overcharging while allowing others in the pack to continue charging.

With many battery types, such as lithium ion or nickel cadmium, a BMS is absolutely required, since overcharging can result in a fire. Though optional with flooded lead-acid batteries, battery management systems will help extend battery life while reducing how frequently you will need to water your batteries. Plus, they help keep the battery pack cleaner—given that overcharging leads to excessive gassing of flooded batteries, which causes some electrolyte to escape and coat the battery tops.

8. Instrumentation

Because running out of charge is even less fun than running out of gas, every EV should have some type of "fuel gauge." As in an ICE vehicle, a fuel gauge in an EV usually reads from zero ("empty") to 100% ("full"). A voltmeter shows the exact voltage of your battery pack at any given moment; a state-of-charge meter shows amp-hours or watt-hours.

Amp-hour and watt-hour meters do not actually measure the charge of the battery pack. They are initially calibrated to "full." From there, they monitor the electricity drawn out of the batteries by driving, as well as the electricity put back in by charging and regenerative braking. With that information, the meters calculate the vehicle's current state of charge.

Another useful instrument is an ammeter, which is essentially an efficiency gauge that tells you how much amperage the motor is drawing at a given moment. Once you become accustomed to reading it, the ammeter can fine-tune the efficiency of your driving style by helping you choose the most efficient (lowest current draw) gear for your speed. It can also alert you to possible problems, such as a slow leak in a tire or dragging brakes that will cause higher-than-normal current draw.

The volt, state-of-charge, and ammeter gauges, with the main breaker/disconnect below.

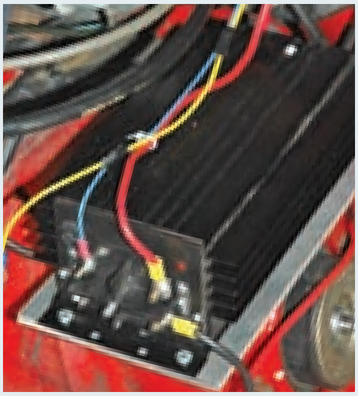
9. Emergency Disconnects

Safety is key when working with electricity. That's why all EVs should have at least one emergency disconnect to break the circuit and disable the system in the event of a collision or other emergency. Disconnects also come in handy when you want added safety while working under the hood.

For extra safety, redundancy is always a good idea. Having more than one disconnect is advisable, since different types are designed to respond to different emergencies. The standard mix of disconnects includes fuses, circuit breakers, and a "panic button" that breaks the high-voltage circuit. Some disconnects work automatically, while others are activated manually.

10. DC/DC Converter

While an EV's main drive system runs on higher voltage, the vehicle's accessories, such the horn, radio, lights, and windshield wipers, run on 12 volts. In an EV, the DC/DC converter takes over the job of an ICE car's alternator. The high voltage of the battery pack is tapped at a low amperage and converted to low voltage at a slightly higher amperage to power the accessories. For example, the converter may initially draw 144 V from the main battery pack at 6 amps. (Compared to the 100 A or greater draw the vehicle uses for cruising at a steady speed, this is a trivial amount.) It then puts out a regulated 13.5 V to 14 V at 25 A or more—the same output you get from an ICE car's alternator. The converter may power the accessory system directly or it may charge a 12 V battery that is separate from the main battery pack.



Brakes & Tires

Running a car safely and efficiently on electricity means more than just adding an electric power train.

Brakes. You want the best brakes you can get, due to the extra vehicle weight from the heavy battery pack. An EV will probably have power brakes that can be operated by an electric vacuum pump with a switch and reservoir. In a conversion, brakes can sometimes be upgraded by substituting parts from a different model vehicle. This might mean a heavier-duty pad and rotor system, or replacing drum brakes with rotors.

Tires. Tires will affect rolling resistance and amperage draw, impacting the EV's economy and efficiency. Fat tires, extra big wheels, or extra small wheels will all cost extra amps—and dollars. Normal-size tires for your model vehicle, especially ones designated "fuel economy" tires, are best. Keep them well inflated, which generally means at the rated limit stamped on the tires. Low-rolling-resistance tires are available in some common sizes, to further decrease rolling friction.

Access

Shari Prange (electro@cruzio.com) married into Electro Automotive, an electric car conversion parts supplier, in 1984. Her EV knowledge came through on-the-job training, and participation in numerous electric vehicle rallies and conferences. She and her husband co-authored *Convert It*, a how-to EV conversion manual.

SINGLE-TANK SOLAR WATER SYSTEMS

by John Patterson & Suzanne Olsen
photos by Suzanne Olsen

No space for a traditional two-tank solar hot water system? No problem. Single-tank solar water heating systems offer great performance and high efficiency, all in one small footprint.

A single-tank solar water heating system combines solar preheated water and backup heating into one tank, in contrast to a typical two-tank system, which separates these functions. Both single-tank and two-tank solar hot water heating systems can save 55% to 85% on water heating costs, depending on your local climate. Considering that water heating is the second-largest energy guzzler in most homes, this translates into serious savings over the long haul, since solar hot water systems have an expected life between 15 and 30 years. But does one system have an advantage over the other?

Yes, says University of Oregon researcher Steve Baker. In the 1980s, Baker monitored 37 solar water heating systems, both single tank and two tank, for the Oregon Department of Energy (ODOE), using common electric water heaters as a standard of comparison. Oregon enacted a solar energy tax credit in the late 1970s, and ODOE wanted to find out how the systems were performing.

The monitoring study found that the typical total energy use for household water heating was about 5,000 kilowatt-hours per year. Several SHW systems in the sunnier parts of the state were able to meet more than 80% of the yearly hot water loads. The study also found that single-tank solar water heaters often saved more energy than a comparable two-tank system.

When space is at a premium, a single-tank solar hot water system (left) offers high performance in a smaller footprint than a typical two-tank setup (right).

Most single-tank solar water heaters feature a 240-volt electric element in the top half of the tank.

A typical timer used for electric water heater elements has adjustable setpoints.

Single-Tank Performance

Single-tank systems performed better for two reasons related to the two loads of water heating. First is the amount of energy needed to raise the temperature of cold water coming into the home (about 50°F) to the temperature setting of most water heaters (120°F). Second is the energy needed to maintain the water heater at the desired temperature throughout the day and night—even when no hot water is being used. This is known as the standby load or standby loss.

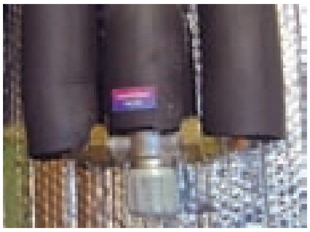
In a two-tank SHW system, heated water from the solar collectors is stored in a solar preheat tank located near a backup water heater. Household water pressure pushes the preheated water from the storage tank into the backup water heater when hot water taps are opened. During the sunny, warm season, the solar preheated water usually remains above 120°F and the backup water heater doesn't need to come on at all. But in the winter, when the temperature of the solar preheated water typically ranges from 60°F to 100°F, the backup heater works to boost the water temperature to 120°F. In a two-tank system, when hot water isn't being used, the water in the backup heater cools and the heater comes on—even if the solar tank is full of 120°F water. Maintaining this standby load can account for 15% to 20% of the total energy used for water heating.

In contrast, most single-tank solar water heaters feature a 240-volt electric heating element in the top half of the tank. The element heats the water in the upper half of the tank, while the water in the bottom half is heated by the solar collectors. Water in the tank naturally stratifies, with warmer water rising to the top and cooler water sinking to the bottom. In a single-tank system, the solar collectors can heat water well above the electric element's thermostat setting of 120°F (130°F to 150°F is common). Because of this, the tank water may remain above 120°F even if it cools by 5°F to 10°F overnight. The result? The element in the single-tank heater doesn't need to kick on at all, yielding a 10% to 20% savings advantage in standby losses compared to two-tank systems.

Because of the inherent inefficiency of gas water heaters, the difference is even greater if the backup water heater in the two-tank system is fueled by natural gas. Until recently, natural gas was less expensive than electricity, so gas water heaters got away with having lower efficiencies. But cheap gas is no longer available in most of the country. When the burner is firing, or even between uses, unused heat escapes up the flue. This, coupled with standby loads, can amount to 20% to 30% of the entire water-heating load. A single-tank system with backup electric heating offers at least an additional 10% energy savings compared to a two-tank system with natural gas backup. When a single-tank system replaces a gas water heater with a continuously burning pilot light, the savings can be 20% or more.

The efficiency of single-tank systems increases when a timer is used.

A tempering valve adds enough cold water to prevent too-hot water from being delivered to end-use points.



Shrinking Your Footprint

If the environmental impact of your energy choices is important to you, a single-tank system can offer impressive savings. Here's the skinny on shrinking your household's greenhouse gas emissions where water heating is concerned.

Of water-heating appliances, tank-style water heaters fueled with natural gas can create some of the greatest carbon dioxide emissions—a ton or more of CO_2 per year. Replacing a gas-fired tank-style heater with a *tankless* gas water heater can cut these emissions by about 15%. Combining a solar preheating system with a tankless backup is a much bigger step in reducing your environmental footprint—at least four times greater (60%) in terms of energy and environmental savings.

Because sources of electricity vary, it's more difficult to determine the amount of CO_2 produced from the electricity used to heat water. Most of the electrical generation in the United States is from coal, which produces copious amounts of CO_2. However, if you live in a region of the country where hydro is used to generate electricity (up to 40% of the electricity supply in some areas), your carbon footprint is proportionally reduced. Ask your local utility for its percentages. If they participate in "green" energy options, pony up to purchase clean, renewably generated electricity.

If you're using electricity generated from a wind turbine or photovoltaic modules for water heating, you should have a clear CO_2 conscience in regard to water heating. But whatever your source of energy, if you use solar thermal as your primary heat source, you'll achieve 55% to 85% of your water heating with the energy of the sun.

In any two-tank system, whether electric or gas backup, heat loss through the insulation of the backup tank and between the pipes going in and out of the tanks can also contribute to standby losses. Of course, this is true for a single-tank system too, but to a lesser degree, since there's only one tank wall and less piping. When the two tanks are combined into one, energy use that typically goes to standby losses can be reduced.

It's All in the Timing

The efficiency of single-tank systems can be further improved when a timer is included. Using a timer accommodates the typical hot water habits of most households, where usage normally occurs first thing in the morning and again in the evening. During midday, when the house is unoccupied, the timer shuts off the element, giving the solar collectors the opportunity to heat the entire tank—even the top portion. The timer can be set to activate the heater an hour or so before wake-up to ensure ample hot water in the morning, and also programmed to allow the element to come on again for evening hot water use. Committing to a timer may mean altering your lifestyle so that you preplan your hot water usage. If you are typically at home during the day, having a timer turn off the tank's heating element will leave you without hot water on cloudy days. However, in many cases, having a timer turn off the electric water heating element at night is convenient and well worth it. And if you plan ahead—showering and doing laundry in the morning, for instance—a timer can save you money without cramping your lifestyle.

Allowing the single-tank system to utilize as much solar energy as possible will cut energy costs. During the middle of the day, the sun's energy can take over, heating water in the tank to 130°F or higher. When this happens, the tank can incur standby losses of 8°F to 10°F and still keep the water temperature above the electric element's 120°F setpoint, effectively keeping the element off. If this occurs half of the year, overall standby losses are cut in half. And it does no harm

(continued on page 46)

Single-Tank Considerations

The freeze-protection approach for single-tank systems can be either drainback or closed-loop glycol, so there's a lot of design flexibility and component options. The best approach will depend on your local climate and the ease of installation of one system type or the other at your home.

If your household is four people or fewer, and your water use is somewhat routine, consider a single-tank system. If space is an issue, the single-tank system may be your only choice. But perhaps the better question is, "Is there anyone who shouldn't consider a single-tank system?"

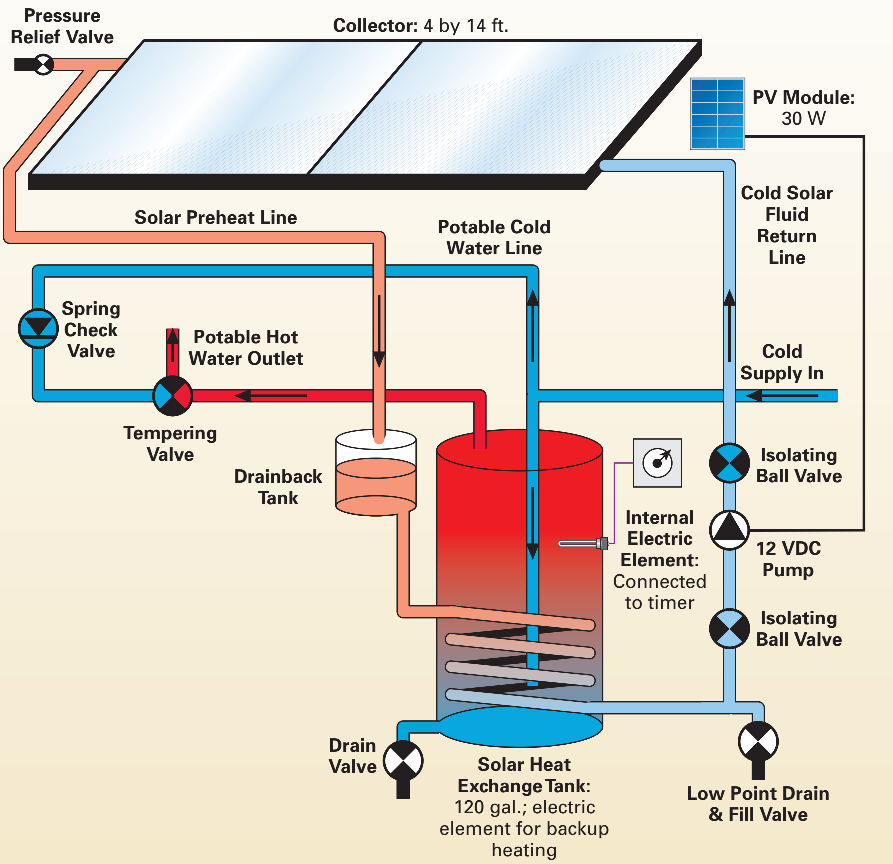
If you have five or more in your household, or use large amounts of hot water, the extra capacity of a two-tank system certainly has value. If you have the problem of frequently running out of hot water (teenagers, perhaps?), then you may need all the hot water you can get. A single-tank system is a good fit for conservationists—but if you've tried everything you can and still don't have enough hot water, then stick with two tanks. Something as simple as installing 1.5 gpm, low-flow showerheads instead of conventional 2.5 gpm showerheads can be enough to solve the problem of not having enough hot water from a single-tank system.

If you currently have a gas-fired tank-style water heater and there's no room for an additional 240 VAC breaker in your electrical panel, then putting in new electrical service just to add the hot water circuit might not be cost-effective. If this is the case, you can still install a solar hot water system—just keep the existing tank heater or use a gas-fired tankless backup water heater. However, be aware that tankless heaters, especially gas models with venting requirements, can be expensive, and their savings are not as great as most people anticipate.

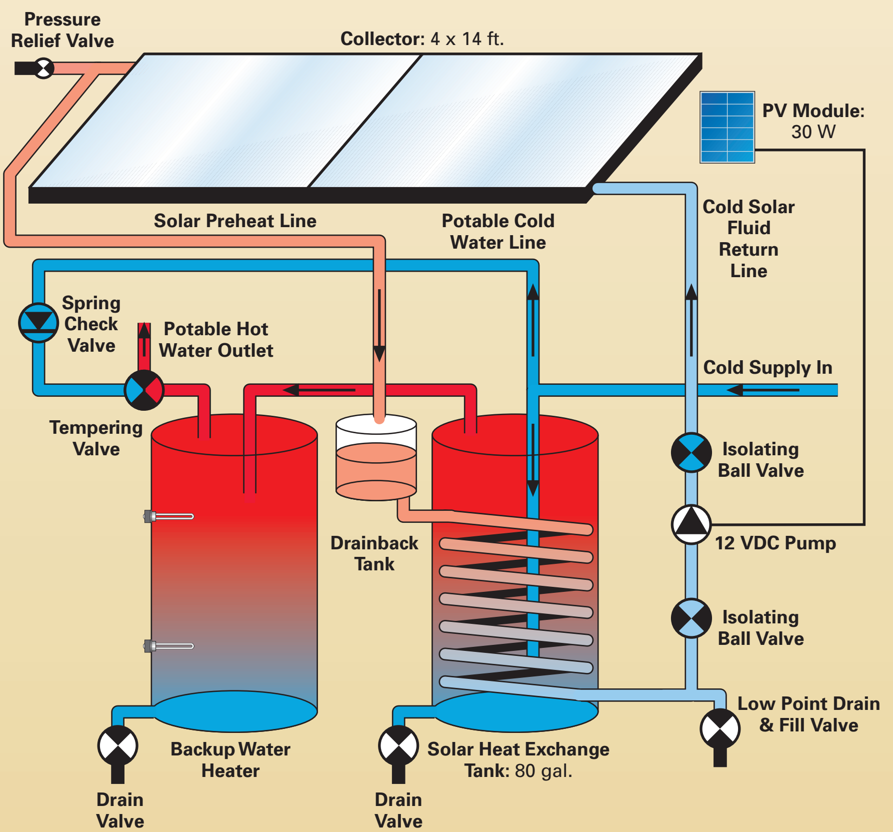
One disadvantage of a single-tank system is occasionally not having enough hot water when use is unusually high and sunshine is unusually low. Single-tank system owner Geri Bogart from Baker City, Oregon, reported that she ran out of hot water for the first time over Christmas when there were four extra houseguests and no sun for days. "I figured out I just had to space out hot water use, allowing a half hour or so between showers. Then everything was fine."

Single tanks can also be expensive to replace if they fail ($1,800, plus a half-day's labor at a plumber's rates). But tanks can last 20 to 30 years if the anode rod is routinely replaced. (See "New Life for Your Old Water Heater" in *HP106*.)

SINGLE-TANK DRAINBACK SYSTEM



TWO-TANK DRAINBACK SYSTEM



Typical Single-Tank Drainback System Costs

Item	Cost
Solar heat-exchange tank, 120 gal.	$1,800
Solar hot water collector, 40 sq. ft.	950
Miscellaneous piping, insulation & valves	500
PV-powered pumping system and control	480
Other (collector mount, miscellaneous)	100
Flow meter	90
Timer	60
Temperature gauge	30
Total	$4,010

to store hotter water in the tank—a mixing valve adds enough cold water in the pipes to keep the temperature at 120°F when it comes out of the hot water tap.

At night, having the timer turn off the element can save on standby losses too. Although it seems like this strategy would require more energy the next morning to raise the temperature again, heat loss occurs at a rate directly proportional to the difference in temperatures. A 120°F tank of water in a 50°F garage has a 70°F difference in temperature, or ΔT. When the tank's temperature drops to 110°F, the ΔT is reduced to 60°F, with a corresponding drop in the *rate* of heat loss. As the temperature drops, the percentage of heat loss drops as well. Even though the backup heater will be on longer first thing in the morning, it will not be on as long as it would have been if it had to maintain the temperature at 120°F through the night. Over the entire year, this amounts to many KWH of energy savings.

SHW System Costs

For most single-tank solar water heater systems, a 120-gallon tank will provide the best service. The single 4,500-watt element is strategically located a few inches above the middle of the tank and will effectively heat about 50 gallons of water electrically, with the remaining 70 gallons in the bottom portion of the tank heated by the sun. Although 80-gallon tanks are available, you'll run the risk of not having enough hot water on rainy days because the element will only heat the top 30 gallons.

For $4,000 to $5,000, you can purchase a single-tank drainback system kit that includes 40 square feet of solar thermal collectors, a 120-gallon tank heater, and all the other needed components. If you want to purchase the components separately, calculate your collector area based on the water in the tank that will be heated by the sun. In a 120-gallon tank, that would be the bottom 70 gallons. Divide this number by 1.5 to 2 gallons to get the recommended collector square footage. In general, most single-tank systems work well with a 120-gallon tank and a collector area between about 40 and 60 square feet.

Federal tax incentives can help offset costs of a SHW system, and many states, cities, and local utility districts have incentives as well. The current federal tax credit pays 30% of a solar hot water system's cost, up to $2,000. However, qualified systems must be installed and operational on or before December 31, 2008, to receive the federal tax credit. And at least a dozen states offer incentives based on cost or performance, usually topping out at about $1,500. Utility incentives are also available in many regions of the country. To check incentives in your area, visit the Database of State Incentives for Renewables & Efficiency at www.dsireusa.org. You can also contact your local utility or solar contractor to find out what's available.

Conservation Pays

Keen energy awareness and dedicated conservation tactics can really make a single-tank system pay off, especially when coupled with a timer. There are always ways to conserve more, such as using low-flow showerheads and using hot water sparingly during cloudy weather. As your usage shrinks, the ratio of water heating by the sun increases. A retired couple from Portland, Oregon, once told me that I misrepresented their solar savings from the system I'd installed a year before. I was perplexed, since I had conservatively told them that they could expect to cut their water heating costs by 55% to 60%. But then they told me that their actual energy savings was 70%. I was amazed. After all, we're talking Portland, a place known for its soggy skies.

The key to the couple's exceptional savings was their enthusiasm. They were excited about their system and made the most of it, spreading their hot water use through the day to optimize solar efficiency and waiting for sunny days to wash clothes. Some of us don't want to change our lifestyles to accommodate the sun, but if you're so inclined, you'll reap extra dividends.

Single-Tank Success

Allen and Laura Bernstein installed a single-tank water heating system in August 2007, when their old water heater needed to be replaced. "We went with a single-tank system because we only had space for one tank in the laundry room," says Allen. The tank wedges between the wall and the laundry sink, with only a scant half inch to spare.

For their two-person household, the setup is ideal. They are energy-conscious and conservation-minded, and their routines allow them to set the timer to garner the most benefit from solar-heating hours. "The system is performing really well," says Allen. "We're getting plenty of hot water."

Allen is so impressed that he's planning to put similar systems on rental property the couple owns. "I think this makes sense for my business, especially with the tax credits available. I have a bunch of water heaters that are at the end of their useful lives and need to be replaced. I'm in the business of providing a comfortable place to live, and I believe my apartments will be more rentable as power rates go up."

Access

John Patterson (jp@mrsunsolar.com) is president of Mr. Sun Solar and inventor of the Sol-Reliant solar water heating system. He has installed more than 1,000 solar water heaters over the past 28 years.

Suzanne Olsen (suzolsen@integra.net) is a writer and photographer specializing in renewable energy and the environment.

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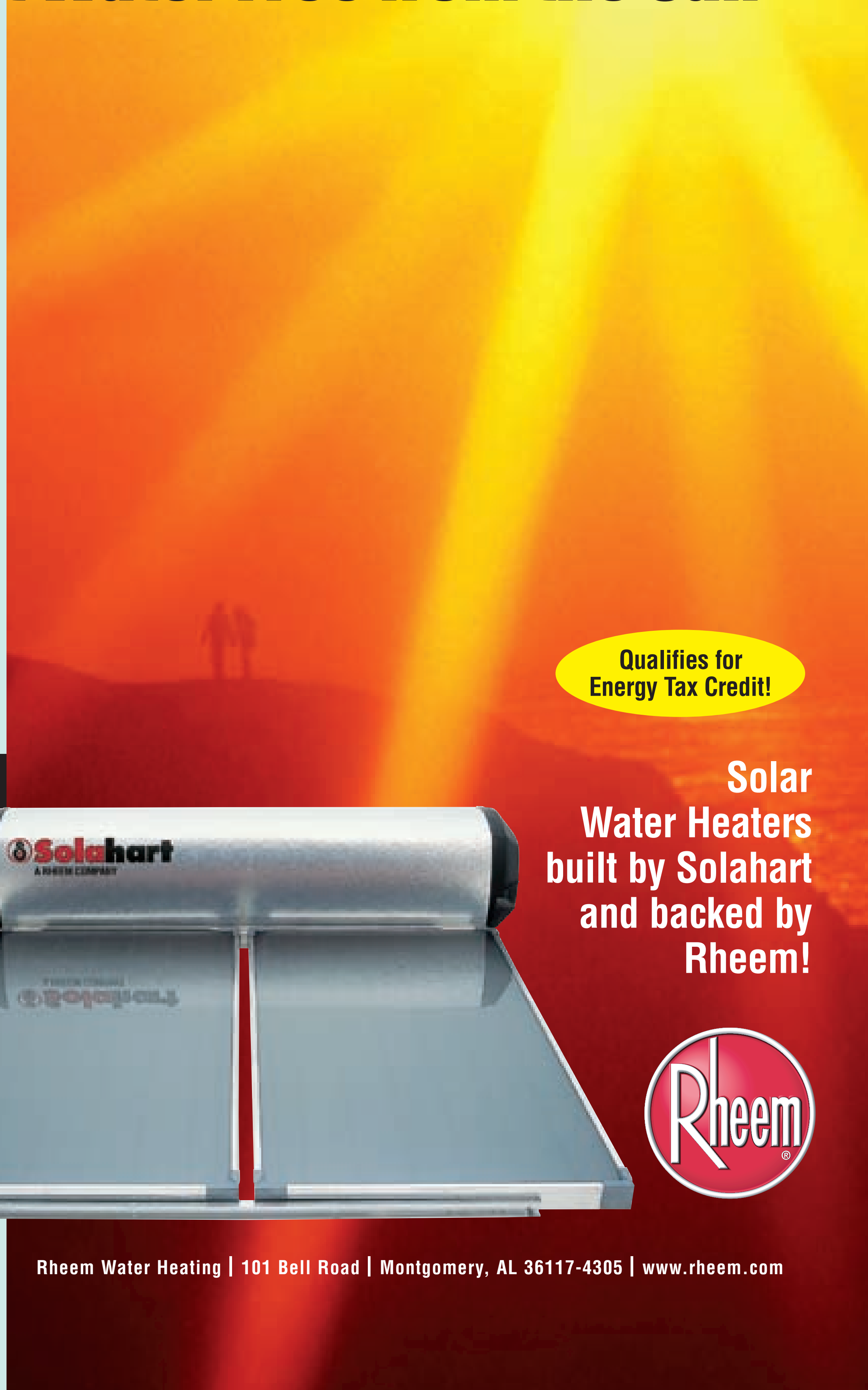

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MAGNUM
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Dan Redmond lives in a 1925 bungalow home with his wife Margaret and two boys, Alec, 6, and Aidan, 3, in Arlington, Virginia. For the past few years, he has had one mission: to change the way his household uses and produces energy. He writes here about how they did it–and what they learned.

LIVING quietly

Story & photos by Dan Redmond

Dan and Margaret's 83-year-old bungalow got a high-tech energy upgrade with a 12-module rooftop PV system.

It was about two years ago when my son, Alec, and I opened a solar power experiment kit that I bought for $10 from a local hobby shop. Since he loves his International Space Station replica, complete with blue solar-electric "arrays," I figured his curious mind might like to see solar power up close. We found a sunny spot in the backyard and laid out all the pieces: a small photovoltaic module, wiring, and a tiny DC motor with plastic fan blades. After a few seconds in the sun, the tiny fan started to whirl. "This," I explained, "is how the International Space Station generates its electricity." Alec was in awe, looking up at the sun and then down at the fan. All it took was one look at my son's face to get me serious about solar energy.

In the months that followed our experiment, I began to research "alternative" energy projects in the United States. A quick browse at our local bookstore turned up *Home Power* magazine, which I consumed in one sitting. Then came hours in front of the computer, perusing various Web sites. I came across one site—Renewable Energy Access—that completely changed my outlook on energy. It suggested that energy use and production could be "quiet"—without pollution, noise, smoke, war, or waste. *Quiet* energy: It almost sounded too good to be true.

Although I had my doubts, I also realized that the world had shifted from burning wood to coal and oil, all in the last 100 years. Why not renewable energy in my lifetime? The more I learned, the more I embraced the idea of quiet energy—and the more I started to believe in its feasibility for our country. Besides the much-talked-about environmental and political advantages, I liked the fact that the growing RE industry could bring new jobs to the United States, especially to

Alec shows off the small PV module that spurred his family's switch to solar electricity.

our hurting manufacturing sector. Parts of the country that have lost jobs to outsourcing and foreign competition could again flourish with production facilities for renewable energy equipment.

I was surprised to learn that renewable energy programs are working more successfully in other countries. Germany and Japan, for example, are prioritizing solar economies. Because they have limited or no domestic sources of coal and oil, and must depend heavily on foreign nations for fossil fuels, their governments have supported aggressive incentive programs that have fostered new business and development in solar and wind energy.

Following the Circuit

Once I understood the feasibility of using renewable energy and realized that it was more than a large-scale experiment, I became a true believer in the power of the sun. My family and I attended a number of RE festivals and events, including the Washington, D.C., Tour of Solar Homes & Buildings in 2005 and 2006. We visited more than a dozen RE-powered homes on those tours, where I marveled at how homeowners were using new approaches to satisfy their everyday energy needs.

Among my favorite events in D.C. was the 2005 Solar Decathlon (see "High Design, High Performance" in *HP123*)—a competition in which custom-designed solar homes are erected on the National Mall and judged on their energy performance. Even during a rainy, gloomy week in October, the project homes powered a gamut of appliances, heating and cooling systems, and even electric cars—with only the power of the sun.

Seeing solar in action convinced Margaret and me to go for it. Using the online directory, www.findsolar.com, I reviewed the qualifications of installers in my area. Then, at the 2006 Washington, D.C., Green Festival, I made a point of visiting the booths for the area's largest solar energy companies—all based in Maryland, where incentives are available.

Making a Connection

Going into the project, we knew that our home's orientation, which offered no south-facing roof space, wasn't ideal. The east-facing rear roof is shaded by tall, dense oak trees. We considered placing a pole-mounted array in the backyard, but didn't want to lose any space for the kids to play or for our garden. Besides, I wanted our PV system to be visible to the community. That left our west-facing front roof, which had an unshaded solar window—from 10 a.m. to 5 p.m.

We chose our solar-electric installers differently than some might, selecting the components we wanted first and then finding a dealer who could source and install them. Knowing that our system would need to be installed on the street-facing side of our home, aesthetics were important to me. I found modules made by SunPower that are completely black, including the frames and mounting system. As it happened, these modules were also the most efficient on the market at

Aidan points out the inverter's remote system monitor mounted on the living room wall.

"It was more important for me to spend our money on modules that generate electricity rather than on batteries to store it."

Making Cents of the Payback

With all the what-ifs of future energy prices, calculating the "payback" of a solar-electric system tends to be a rather convoluted task. Here in Virginia, where coal is abundant and produces most of the electricity, we pay below what most other states pay for electricity, about 9.4 cents per KWH. This "cheap" electricity adds years to the traditional PV payback calculation. However, once the idea of coal-to-oil liquefaction gains momentum and if coal is used for fueling vehicles, the cost of coal-based electricity will inevitably go up. That potential increase could shave years off our payback, but only time will tell.

Our 1,400-square-foot house doubles as an office for my wife Margaret and me; she telecommutes as a consultant for IBM and I work as an architectural photographer. Our office is equipped with a laptop and desktop computer, scanners, a laser printer, and backup hard drives. The combined electrical loads of our computer gear contribute to our having a slightly higher-than-average monthly usage compared to other all-electric households. Prior to our conservation efforts and PV installation, our average monthly use was 1,500 KWH.

After we implemented conservation measures and replaced our old appliances with more efficient Energy Star models, our bill averaged $100 for roughly 900 KWH per month. (See "Our Energy Reduction Plan" on page 54.) Once we added the PV system, our electrical bills dropped even further—about 40%. If we wanted to swelter in Virginia's summer humidity and not run our air-conditioning system, our PV system would come close to meeting our annual electricity needs. Last year, from May to December, our electrical bill averaged $42 per month, with a high of $68 in August and a low of $20 in May.

After the $2,000 federal tax credit, we paid $25,700 for our system, using a taxable savings fund that had big swings in interest payouts. Long warranty periods—10 years on the inverter and 25 years on the modules—take the fear out of the initial investment. Unfortunately, Virginia has been slow to adopt incentives and tax credits. Our system is exempt from state sales and property taxes, but that's about all the state has to offer. If we lived a few miles to the north in D.C., we could have received reimbursement for up to 50% of the system's cost through grants from the D.C. Reliable Energy Trust Fund. A few miles farther north, in Maryland, grants cover up to 20% of a system's cost with a maximum rebate of $3,000 for residential PV systems.

Despite the absence of incentives in Virginia, we have no regrets about our investment. For the next 20 to 30 years, our roof-mounted system will produce a large portion of the electricity we need. Though we're not making a huge return on our investment (about 4% untaxed), we see our system as a safe place to park our cash. The rate of return is roughly equivalent to a conservative bond fund. And, so far, the sun always rises, making the system a stable and reliable investment every day.

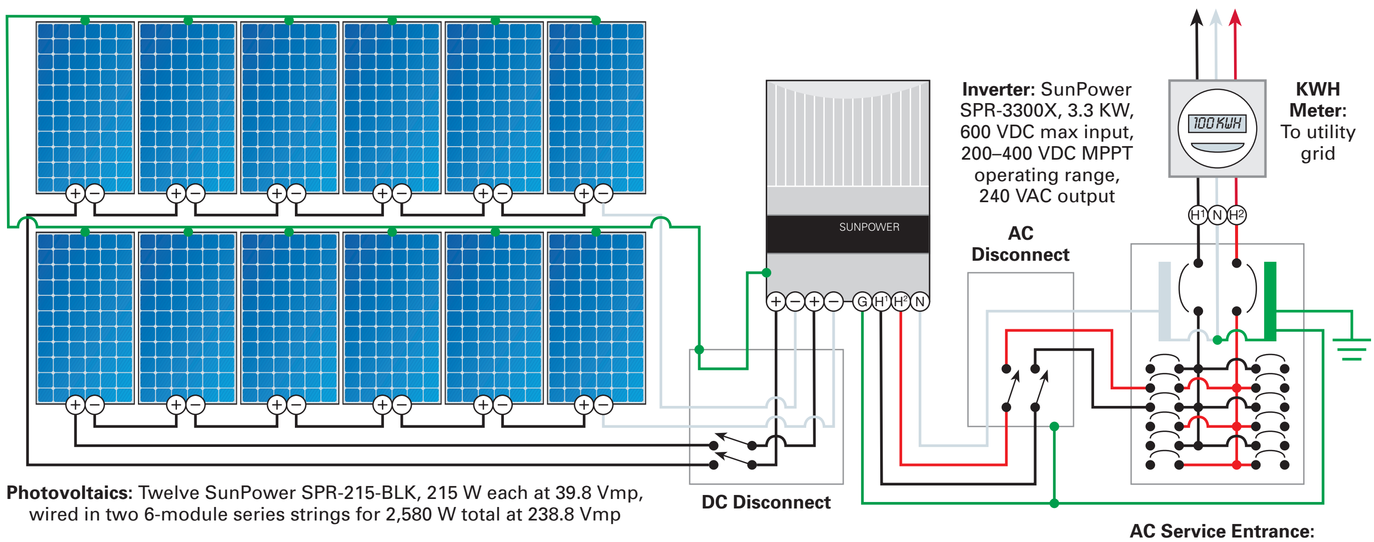
the time, reducing the area needed for the installation on our small roof. SunPower directed me to their local authorized dealer, Standard Solar Inc. of Gaithersburg, Maryland.

I toyed with the idea of doing the installation myself, but I decided to leave the technical work to the pros. Though it cost a little bit more, hiring professional installers is one more way that people can help the industry prosper. Once we gave them the green light last March, it took four weeks to receive the components and then three days to install the system at the house. By the end of April, the system was operational.

The finished product: A 2.6 KW grid-tied solar-electric system with twelve 215 W SunPower modules on the roof and a SunPower 3.3 KW batteryless inverter in the basement. We rarely lose power from the grid, so backup electricity was not a priority. It was more important for me to spend our money on modules that *generate* electricity rather than on batteries to store it.

This grid-tied PV system allows Dan and Margaret to enjoy lower electric bills while reducing their consumption of fossil fuels.

Redmond On-Grid PV System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

Running the Numbers

One of the system's coolest features is a remote monitor in our living room that enables us to view the PV system's performance. The monitor tells us how many kilowatts are being produced at that moment, as well as to-date total KWH production (1,715 KWH), financial savings ($240 as of January), and carbon offset in pounds (2,100 pounds).

Because we positioned the modules on the west-facing front roof, the system works predominantly in the afternoon. Had we been able to face the modules south, we could have gained at least 10% in system output. Even still, the system has exceeded our expectations. As of early January, the system had generated more than 1,700 KWH of electricity since its installation in April 2007. The system was most productive

(continued on page 55)

PV pros Matt Griffiths and Kevin Higgins of Standard Solar secure modules to the rooftop mounting rails.

Inset: The SunPower inverter is located in the basement, where it is out of the way yet readily accessible.

"Besides producing pollution-free electricity on site, the system is virtually maintenance free."

Our Energy Reduction Plan

Years before we got serious about our mission to live with solar electricity, my wife and I decided that we needed to do our part to save energy and reduce our utility bills. Our energy reduction plan evolved over several years. On paper, it may look like we have been very organized in this process. But, in reality, we made changes as we went along, adapting our lifestyle as we learned about new ways to efficiently use energy in our home. Here are a few of the baby steps that led to our final leap into solar electricity.

Step One. Long before the buzz about compact fluorescent (CF) lightbulbs, we swapped all our standard incandescent bulbs with high-efficiency CFs—which use about 75% less energy and last up to four times longer. Back then, there wasn't much in the way of selection, and prices were on the high side. Today, a four-pack of 13 W bulbs (equivalent to 60 W incandescents) costs about $10, and bulbs in every size and shape accommodate a variety of fixtures and uses. Improved phosphor formulations have virtually eliminated the harsh fluorescent glare that once gave CFs a bad reputation.

Step Two. Since many of our appliances were nearing the end of their life expectancy, the timing was right to start replacing them with energy-efficient models. To spread out the cost over time, we replaced one major appliance per year with Energy Star-rated models. First came the dishwasher, second a refrigerator, and then, a horizontal-axis energy- and water-saving clothes washer. With two adventurous boys, we do lots of laundry. The new washer alone has reduced our water consumption by 8,000 gallons per year. Whenever the weather cooperates, we dry laundry on a Breezecatcher rotating clothesline.

Step Three. A story in *Home Power* introduced me to UltraTouch, a recycled denim insulation. At 5.5 inches thick, it has an R-19 insulation value. I loved the idea of using a nontoxic material that required no gloves or masks. For only $300, I insulated two-thirds of our bungalow's main subfloor area. The material stays in place between the floor joists without staples or nails. New windows are coming soon, but for now, the insulation makes a huge difference.

The Redmonds replaced their second car with more sustainable transportation—an electric bicycle that's charged by their PV system.

Aidan patiently waits for another delicious treat baked in the family's solar oven.

Step Four. At a home-improvement store, I spotted a stack of 10 W PV modules that are used to power vent fans and wondered what else I could use them for. I bought three, and paired them with a single, deep-cycle marine battery and an 800 W inverter. We power all sorts of devices by plugging into the inverter's outlets. Small power tools, lamps, stereos, and even an electric vehicle—well, my boys' battery-operated Power Wheels kiddie car.

Step Five. Given our success with my sons' Power Wheels, we decided to use solar power for bigger wheels. We replaced our second car with an electric bicycle for local commuting and errands. An attached trailer enables me to take the boys to school and leaves room for groceries on the return trip home.

Step Six. After we learned that solar cooking is a relatively simple way to reduce everyday energy needs, we purchased a solar oven and started experimenting. We started with simple things, like cornbread and brownies. Soon, we graduated to chicken, potatoes, rice dishes, and casseroles. All year long, we see the savings in our gas bill. In the summer, outside cooking in a solar oven helps keep the house cooler. The best part: Aidan, my youngest son, now accepts renewable energy as a way of life. One day, when I declined his request to make brownies, he said emphatically, "But daddy, the sun is shining!"

Sources:

Bonded Logic Inc. • www.bondedlogic.com • Recycled denim insulation

Breezecatcher clothes dryers • www.breezecatcher.com • Rotating clothesline

Powabyke Ltd. • www.powabyke.com • Electric bike

Solar Ovens International Inc. • www.sunoven.com • Solar oven

> "Just as you don't have to know how a car works to drive one, you don't have to be an electrical engineer to use solar electricity in your home."

last spring, producing 10 KWH on sunny days. However, the dark days of winter take their toll on performance, when we get only about 3 KWH per day.

Any excess electricity that our system produces and we don't use is sent back to the grid. Our KWH meter records this savings much like a deposit into the bank. When the sun is not shining, our household draws electricity from the grid—similar to withdrawing some savings from the bank. At the end of the month, the difference is calculated between the electricity we generate and the total electricity we actually use. That amount makes up our electrical bill. Any net excess is credited to our next month's bill.

Living with Solar

In retrospect, I didn't need to do as much research as I did. For me, learning was part of the process. Knowing what I know now, I am confident that I could have simply picked up the phone, written a check, and had a great system installed—because just as you don't have to know how a car works to drive one, you don't have to be an electrical engineer to use solar electricity in your home.

Besides producing pollution-free electricity on site, the system is virtually maintenance free. During pollen season and occasional dusty periods from nearby construction, I used a garden hose to rinse off the modules—since modules are most efficient when they're clean. Otherwise, system operation is effortless. It starts generating electricity automatically as soon as sunlight hits the PV array and goes off-line at dusk. It's that easy. And that quiet.

Access

Dan Redmond (redmondDK@mac.com; www.danredmond.com) grew up near the coal mines of West Virginia and understands firsthand the effects of the United States' "cheap" electricity. Eventually, he hopes to add a solar hot water system to the house and replace the family car with a plug-in electric vehicle.

Standard Solar Inc. • 888-474-3843 • www.standardsolar.com • Installer

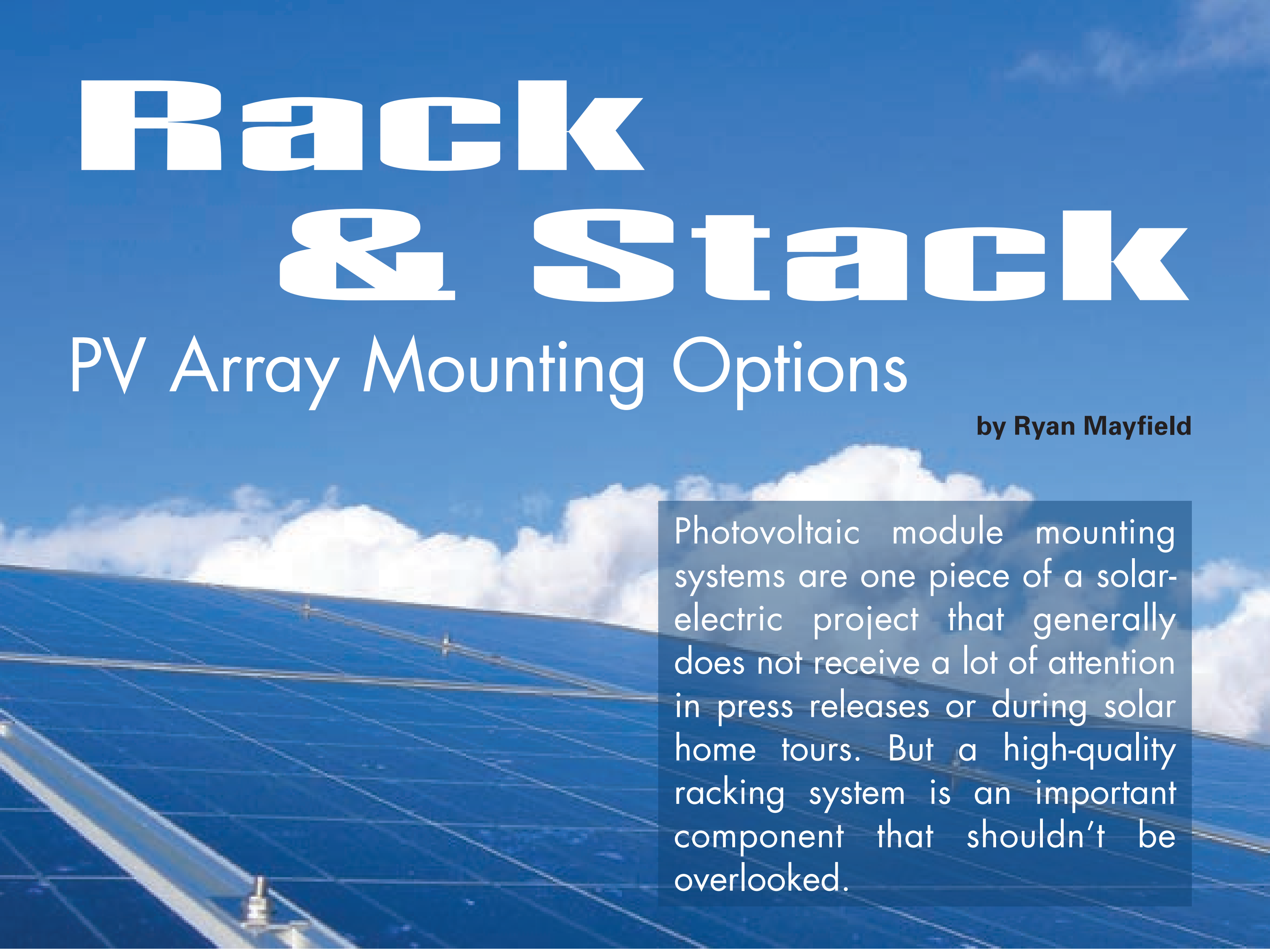
PV System Components:

SunPower • www.sunpowercorp.com • PV modules & inverter

Rack & Stack

PV Array Mounting Options

by Ryan Mayfield



Photovoltaic module mounting systems are one piece of a solar-electric project that generally does not receive a lot of attention in press releases or during solar home tours. But a high-quality racking system is an important component that shouldn't be overlooked.

For most PV applications, gone are the days of having to custom-manufacture a mounting system. Many commercially available solutions exist—from pole-top module mounts to rooftop rails. This guide will help you navigate the variety of options available today and their associated advantages to fit your specific application.

Top-down rail mounts are popular in both home- and business-scale installations.

Mounting clips attach PV modules to the rails from the top, allowing quicker installations.

Top-Down Rail Systems

One of the most common—and very popular—PV module mounting methods is the "top-down" rail system, since modules attach from their upper side to the rails with specified clamps. This versatile system can be used with almost all roofing types. Top-down mounting systems consist of four main components:

- Feet or posts (also called "footings" or "stand-offs") that are typically secured to the roof's rafter system;
- Extruded aluminum rails fastened to the feet or posts and the array;
- End-clips that secure the ends of the PV array to the rails;
- Mid-clips that hold the junction of two modules to a mounting rail.

Manufacturers of top-down rail systems each take their own approach, with slight nuances on the same basic mounting principles. Mounting rails are extruded lengths of aluminum which allow installers to use standard or mount-specific stainless-steel bolts and mounting clips to attach the PV modules to the rails.

Top-down rail systems offer several advantages for roof-mounted PV arrays. The first is that the array is mounted parallel to the roof plane, which minimizes the array's visual impact compared to other mounting options. Second, the PV modules are attached to the rails from the *front* side, instead of the back, which decreases installation time. Many top-down rail manufacturers have also developed integral array equipment-grounding options.

The adjustable spacing of the footings and rails also offers a flexible design element. Since the feet can be attached to the rails at any place along their length, the exact footing location is inconsequential as long as the spacing between each does not exceed the manufacturer's recommendations. In a top-down system, PV modules can either be placed in a portrait or landscape configuration to accommodate a particular roof's characteristics. Although the rails are generally mounted perpendicular to the rafters, when necessary the rails can be run parallel to the rafters.

The downsides? Rail systems typically result in only 3 to 6 inches of space between the back of the modules and the roof surface. Although this space does allow for some airflow underneath the array, modules mounted this

Courtesy www.conergy.us

Conergy's SunTop rail system offers a flexible, top-down mounting approach for a wide range of roofing materials.

Courtesy www.sharpsolaritson.com (2)

Sharp's top-down mounting rails are one component of their SRS system kits.

Courtesy www.unirac.com

UniRac's module clips used in conjunction with S-5! clamps to mount an array directly to standing-seam roofing.

Courtesy www.electronconnection.com

A DP&W rack sets an angle steeper than the roof pitch. Fixed-pitch and adjustable racks are available.

close to the roof surface tend to reach higher temperatures (more so compared to most other mounting options), which diminishes the amount of power delivered from the array (see "Module Mounts & PV Performance" sidebar). Besides the negative effects of temperature on the array, access to the back of the modules is greatly reduced. However, since the majority of modules are prewired with quick connects and inaccessible junction boxes, access to the backs of the modules will only be necessary if troubleshooting is required. Finally, when the PV array is mounted parallel to the roof's surface, the *roof* dictates the array's tilt angle. Less-than-optimal tilt will result in less-than-optimal performance from your PV array.

Rack Mounts: Adjustable- & Fixed-Tilt

Rack mounts can be tailored to fit a variety of situations, accommodating both ground-mount and roof-mount applications. Perhaps the biggest benefit to racks is that they can allow for a variety of specific tilt angles. The PV array can be set at an optimal tilt angle based on the site's latitude or, if adjustable racks are chosen, repositioned seasonally to optimize energy output.

The back-leg assembly of adjustable rack mounts can either be set to hold the array at a fixed tilt or to be manually adjusted. When an adjustable tilt is required, the tilting legs are manufactured with predrilled holes or slots that correspond to different tilt angles, or with telescoping legs that have specific tilt-angle attachment points or, in some cases, are infinitely adjustable.

Since these mounts tilt the array away from the mounting surface, the backs of the modules can usually be conveniently accessed to get to the wiring, junction boxes, and grounding points, making installation and maintenance easier. The increased distance from the mounting surface also facilitates greater airflow along the back of the modules and results in a lower array temperatures compared to the parallel-to-roof method.

These racks offer a lot of versatility: The same rack can be used for a ground- or roof-mounted array, or even in an awning configuration on the side of a building. The footing attachments also vary, although aluminium angle L-feet and post-type mounting feet are the two most popular options. Some rack mounts are designed for top-down module installation, while others require the modules to be secured from the back. In the latter case, the predrilled holes on the back of a module's frame are used to fasten the PV modules to the rails.

Rack-type mounts have a few disadvantages. Many designs require ordering a specific rack with mounting-hole spacing that matches the PV module's mounting holes. In roof-mounted systems, rack mounts have less layout flexibility than top-down rail systems. Most rack mounts have a fixed distance between the mounting feet based on standard rafter spacing of 24 inches. If the rafter spacing was poorly laid out or based on a nonstandard pattern, adding blocking against the underside of the roof sheathing between the rafters may be required. Finally, rack mounts tilted to angles that significantly differ from a building's roof pitch tend to have a greater aesthetic impact on a building than arrays that are mounted parallel to the roof surface.

(continued on page 62)

A rack-style mount used in an awning configuration.

Courtesy J. Sanchez

Module Mounts & PV Performance

PV system owners get very excited about the number of kilowatt-hours produced by their systems. And for good reason—this electricity is helping to offset their utility bills or, in off-grid scenarios, providing most or all of their electricity. Anything that can help or hinder production should be investigated, and racking methods are no exception.

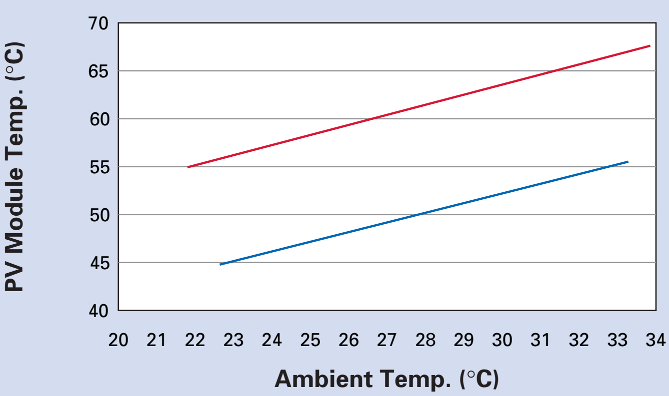
Frank Vignola and his team at the University of Oregon's Solar Radiation Monitoring Laboratory have been collecting environmental and PV system performance data across the Pacific Northwest (see http://solardat.uoregon.edu). This data has enabled PV designers to accurately predict PV array output for a variety of installation conditions—including mounting methods.

Because high temperatures adversely affect a PV system's performance, it's particularly important to try to implement best practices when feasible. In general, arrays that are mounted parallel to the roof surface with less than 6 inches of space between the array and roof will experience cell temperatures of about 35°C (63°F) above ambient temperatures. For rack-mounted arrays, where the back of the array is tilted off the roof surface greater than 6 inches, cell temperatures are estimated to be about 30°C (54°F) above ambient. Top-of-pole mounted arrays will operate at approximately 25°C (45°F) above ambient temperatures. In general, PV array output takes a 0.5% hit for every 1°C rise in temperature.

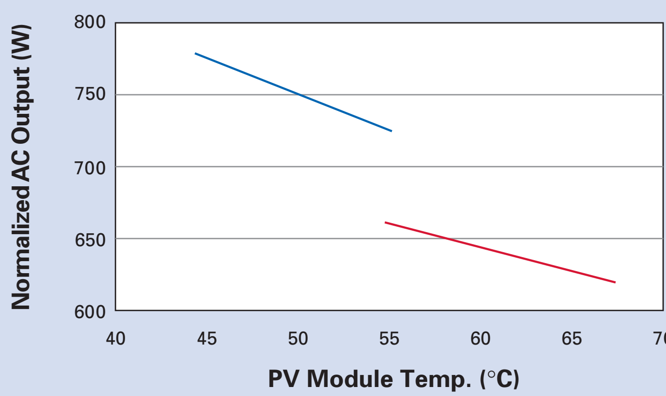
Two other critical array mounting concerns for optimizing system production are the array's orientation (relationship to true south) and the tilt (the array's angle off of horizontal). As a general rule, for a fixed array to produce the maximum amount of energy annually, it should be oriented toward true south (after correcting for magnetic declination), with its tilt angle fixed to correspond to the site's latitude.

However, this general approach can be fine-tuned based on site specifics such as what time of year the most potential solar energy is available, or if the interconnection agreement with the utility is based on annual, rather than monthly, system output. For locations in western Oregon, for example, an array will produce the most energy when oriented slightly west of south at a tilt angle of approximately 30 degrees (approximate latitude minus 15 degrees). In the eastern half of the state, where there is a greater solar resource, the ideal array position is approximately a 35-degree tilt (approximate latitude minus 10 degrees) and either a true south or slightly east-of-south orientation.

Rack Style & Module Temperature



Module Temperature & Performance



Courtesy University of Oregon Solar Radiation Monitoring Laboratory (2)

Rack Mount (Eugene, OR) Parallel-to-Roof Mount (Bend, OR)

The above graphs are based on two different arrays: one in Bend, Oregon, mounted parallel to the roof plane and 4.25 inches above the roof surface, and another in Eugene, Oregon, mounted at a 30-degree angle to a flat roof. For the comparison, only data obtained with incident solar radiation between 900 and 1,000 watts per square meter was used. Data was grouped into four "bins" with ambient temperature between 20 and 24°C, 24 to 28°C, 28 to 32°C, and 32°C and above. The data is represented by trend lines. Exact system performance will vary with local conditions.

The Module Temperature & Performance graph shows the approximate 0.5% decrease in output per 1°C increase in module temperature at each site. The Rack Style & Module Temperature graph illustrates the temperature advantage of mounting PV modules away from the roof plane to increase air circulation and cooling. The modules mounted at a 30-degree angle to the roof stayed about 12°C cooler and performed about 6% better than those flat-mounted 4.25 inches above the roof.

Pole mounts allow easy tilt adjustment and snow clearing, and ample air circulation means cooler modules for more power output.

Top-of-Pole Mounts

The top-of-pole mounting solution is a favorite among many installers for a variety of reasons. The ability to locate an array far away from shading objects, to tilt and orient the array in an ideal position, and to avoid punching a bunch of holes in a customer's roof are all positives. With the advent of high-voltage string inverters, and MPPT controllers that can step down higher-voltage PV arrays to a lower battery charging voltage, pole mounts can be located up to a few hundred feet from the charge controller or inverter. Top-of-pole arrays are viable for locations with enough land space and where possible aesthetic concerns are not an issue.

Depending on the size of the array, the support pole can be as small as 2-inch-diameter schedule 40 steel pipe to 8-inch-diameter schedule 80 for large arrays. The footing for the pole is encased in concrete according to manufacturer's specifications (or local engineering) for the array size and the site's soil and wind-loading conditions. In these setups, the top of the array is generally too high to be easily accessible and a ladder or scaffolding system will be required during installation.

With the exception of the actual pole, which is purchased locally, the mount manufacturer provides all the necessary components and hardware to mount the array. Included are the mounting sleeve, which slips on top of the pole, and all necessary bracing and cross members, as well as module mounting hardware. (See "How to Install a Pole-Mounted Solar-Electric Array: Part 1 & Part 2" in *HP108* & *HP109* for pole-mount installation specifics.)

The ability to adjust the array tilt seasonally is a natural function of any top-of-pole mount. This can be of particular interest for off-gridders who rely on every KWH of electricity produced by their PV systems. In cold climates, top-of-pole mounts are one of the most convenient racking options if snow needs to be periodically cleared from the array. Top-of-pole arrays can also be used with tracker systems to help boost PV production even more (see "Tracker Types & Features" sidebar).

Because the array sits several feet from the ground, allowing for the greatest amount of airflow, top-of-pole mounted arrays operate at lower temperatures than roof- and ground-mounted arrays. This reduces the amount of power lost when ambient temperatures are high.

Top-of-pole mounts generally are not viable options in urban or suburban areas due to the yard space required. And the additional excavation required to place a pole and trench to the electrical distribution can make top-of-pole mounts more costly in certain situations. Finally, side-of-pole mounts, which are popular for small stand-alone outdoor lighting systems, are also available.

Commercial Racking Systems

The proliferation of commercial PV systems has resulted in the advent of a number of different racking approaches for large arrays and installations on flat roofs. These solutions include custom designed and fabricated mounting structures, integrating the PV array into the roofing material, and using a nonpenetrating ballast system for flat-roof applications.

The most common type of commercial racking system is the ballast rack, which uses the weight of the modules and rack in conjunction with ballast to securely keep the arrays in place. Masonry blocks are placed in ballast pans that are located either directly under, or in front of and behind,

(continued on page 64)

Ballast mounts rely on the weight of the ballast, modules, and racking—rather than fasteners and roof penetrations—to secure the array.

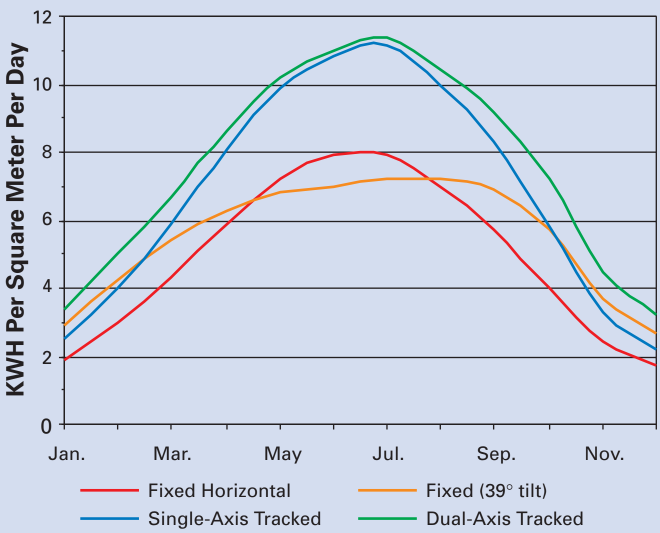
Courtesy www.power-fab.com

Tracker Types & Features

The sun's path through the sky changes throughout the day: In the morning, it's low on the eastern horizon; at noon, it's high in the sky; and at sunset, it's low again, but on the western horizon. Because a PV array generates the most energy when its modules are directly facing the sun, those interested in getting every last watt-hour from their PV modules often investigate tracking systems.

Trackers are available for almost all sizes of PV arrays. For smaller residential applications, tracking systems are commonly mounted on top of an appropriately sized steel pole. Larger commercial systems will often employ long rows of PV modules set on single-axis trackers.

Fixed vs. Tracked Arrays



Courtesy NREL and Array Technologies

A good site for a tracked array receives dawn-to-dusk sun. There's no point in buying a tracker if your site doesn't begin receiving sunlight until 10 in the morning, or loses it at 2 in the afternoon due to shading from hillsides, trees, or buildings. When located at a site with a wide-open solar window, a tracked array will generate approximately 25% to 40% more energy annually than a static array.

There are two forms of PV tracking: single axis and dual axis. The single-axis method follows the sun's path from east to west, with the array tilted at a fixed or manually adjustable angle off the horizon. This approach is common in large-scale, commercial installations but can be used in residential applications as well.

Dual-axis trackers adjust the PV array to track the sun's path from east to west and adjust the array's tilt to account for the change in the sun's altitude.

Trackers come in two basic types: electrically operated and thermally operated (referred to as "active" and "passive"). Common electrically operated trackers for residential systems typically rely on photosensors that signal motors (via a controller) to orient the array toward the sun as its position changes throughout the day. Thermally operated trackers use the transfer of mass (weight) to follow the sun. In a passive system, a canister and shading fin is attached to the east and west sides of the tracker. These tubes are filled with a material—usually Freon—that vaporizes (becomes a gas) at relatively low temperatures. As the sun hits one canister, the warmed Freon vaporizes and pushes some of the cooler liquid Freon to the other side. This process transfers weight from the one side of the tracker to the other and orients the array toward the sun.

Both electrical and thermal trackers have associated advantages and disadvantages. The big advantage of electrical trackers is that they are extremely precise and will generate more energy for a given period than passive trackers. But electrical trackers are not without their weak points. Because they rely on electronics and electric motors, their reliability is lower than thermally operated trackers. Electrical trackers are also sensitive to damage from lightning. The manufacturers of these trackers have made great strides in making their products resistant to lightning damage, but in the event of a close or direct strike, damage still may occur.

Due to their simplicity, thermal trackers have proven to be very durable in the field. On the downside, because they rely on solar heat, these trackers can be slow to respond. At night, they remain facing west and rely on early morning sunlight to return to the east. This process may take an hour or more depending on ambient temperature. In winter weather, thermal trackers can be somewhat sluggish and imprecise in performance because they are dependent on building up enough heat to vaporize the Freon.

Whether a tracker will be cost effective for your application will depend in part on your seasonal electrical use patterns. Trackers give you more gain in the summer when the days are longer, with somewhat less improvement in the winter. For grid-tied systems with annual net metering, this can be a bonus because the tracker's excess summer production will help offset your winter utility bill. In PV-direct (batteryless) water-pumping systems, trackers with as few as two PV modules can be cost-effective compared to buying additional modules to pump the amount of water required.

Array Technologies' Wattsun active tracker.

Wattsun tracker gimble and drive system.

Courtesy www.wattsun.com (2)

The Zomeworks passive tracker functions by thermal phase change.

Courtesy www.zomeworks.com

the PV array. These racks can add a significant roof load, up to 30 pounds per square foot, depending on the array engineering requirements. In an effort to minimize roof loading, there are also mounting systems that use ballast in conjunction with roof attachments to help minimize both roof penetrations and excessive loading on the roof structure. Ballast racks are available from manufacturers in both fixed and adjustable tilts. The low fixed-tilt-angle models (5 to 10 degrees) generally require less ballast and can be used in higher wind-speed areas than the taller, adjustable racks.

Access

Ryan Mayfield (ryan@mayfieldsolar.com) has a degree in environmental engineering from Humboldt State University and lives in Corvallis, Oregon. He teaches PV classes at Lane Community College and Solar Energy International, and runs Mayfield Solar Design, a firm focusing on PV system design, implementation, commissioning, and industry-related training. He holds a Renewable Energy Technician license in Oregon.

Mount Manufacturers:

Conergy • www.conergy.us • Top-down rail

Direct Power & Water • www.directpower.com • Top-down rail, top-of-pole, rack & ballasted

General Specialties • 208-265-5244 • Top-of-pole

Lorentz • www.lorentz.de • Active trackers

PVee • www.pvee.net • Active trackers; custom rack & ballasted for commercial applications

ProSolar • www.prosolar.com • Top-down rail

Schuco • www.schuco-usa.com • Top-down rail

Sharp • www.sharpsolaritson.com • Top-down rail kit

Solar Racks • 707-826-9214 • Rack

Sun Earth • www.sunearthinc.com • Top-down rail

SunPower • www.sunpowercorp.com • Top-down rail kit, commercial ballasts, & trackers

UniRac • www.unirac.com • Top-down rail, rack, ballasted, & custom commercial

Wattsun • www.wattsun.com • Active trackers

Zomeworks • www.zomeworks.com • Passive trackers, rack & top-of-pole

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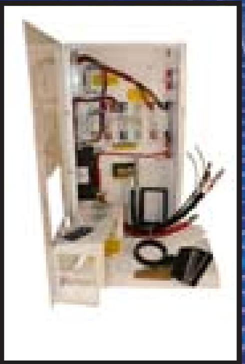

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GPS monitoring station at Cape Roberts, Antarctica operates year-round with solar power and a large bank of Deka Solar Gel Batteries.

Photo Courtesy of UNAVCO

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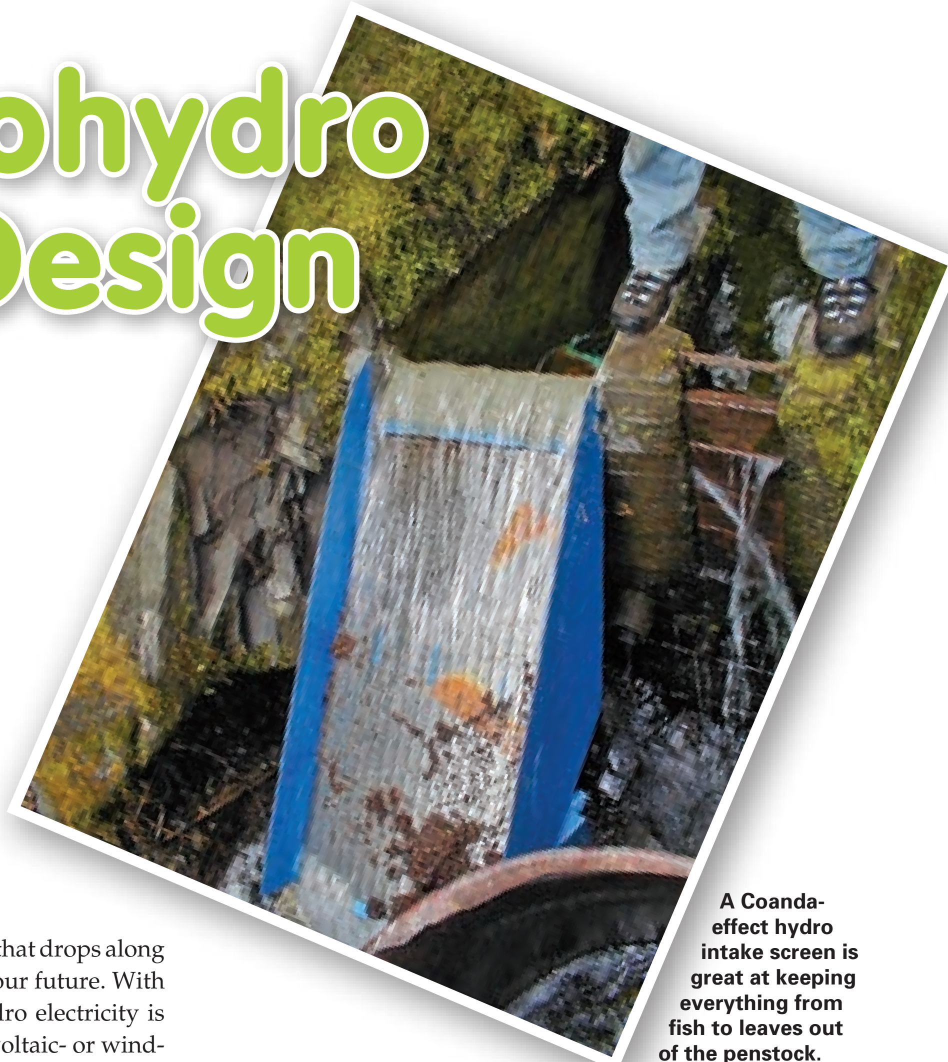
Microhydro Intake Design

by Jerry Ostermeier



A Coanda-effect hydro intake screen is great at keeping everything from fish to leaves out of the penstock.

If you have a creek or stream on your property that drops along its course, a microhydro system could be in your future. With the right circumstances, harnessing microhydro electricity is cheaper and more constant than either photovoltaic- or wind-powered electricity, partly because a source of flowing water is available 24/7, and not vulnerable to doldrums, clouds, or the number of daylight hours.

While a microhydro system requires a more hands-on approach than PV, it is often simpler for the system owner than harnessing wind. It can also be a great do-it-yourself project—if you have the appropriate knowledge and skills. Supplying debris-free water to the hydro turbine is the first critical step in developing a low-maintenance hydro system. This article will introduce you to several methods of constructing an *intake* to do just that. Keep an eye out for additional articles that will cover penstock (the pipeline to the turbine) design, and system wiring and transmission voltage considerations for high- and medium-head microhydro systems.

Creating a Diversion

If you follow a molecule of water through any high- or medium-head hydro-electric project, the first step is diverting it from its flowing source and into the penstock. A diversion can be a collection pond, a river-wide dam, or even a pile of rocks that backs up the water in a creek enough to cover an intake. A diversion can be simple or elaborate, inexpensive or costly—but it needs to suit your application in a mechanical sense and also in an ecological one—without disturbing fish or their habitat.

This article does not cover some aspects of water diversion, like dam or pond building, since their construction is site specific and can be quite complex, usually requiring professional design and engineering. They also often require permission and permits from government agencies, such as your state's fish and game department, and may need to include mitigation measures to protect fish and other wildlife.

Any diversion and intake needs to be robust enough to withstand the worst that winter has to offer—or it should be removable or easy to repair. Creeks can roll boulders or float trees that can damage your intake and diversion significantly. Some creeks flow evenly year-round, while others may trickle in the summer and flood in the winter. Because every site is a little different, whatever intake method you choose will need to be adapted to work at your particular location.

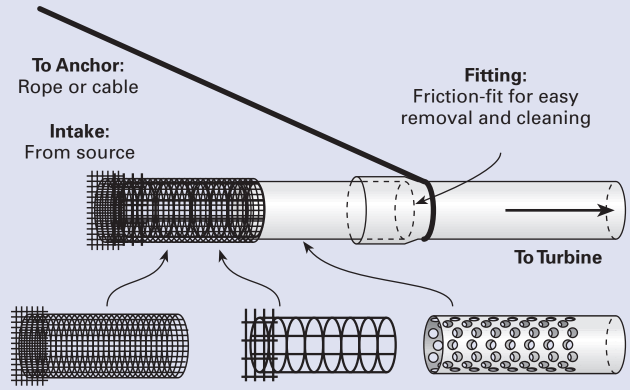
An important job of an intake is to screen out rocks and other debris, $^{1}/_{4}$-inch and larger, and anything that could lodge in the nozzles that direct the water stream onto the runner (the "wheel" in a turbine that is spun by the pressurized water). It also needs to keep out critters, like fish and other swimmers, and inhibit air bubbles from entering the pipe. For some turbine runners in high-head installations, it's also best to filter out the fines (very small particles). Included in this article are the most common intakes used for this class of hydro, with pros and cons for each. Costs will depend upon its size and the choice of materials.

Simple Pipe with Screen

Benefits: Inexpensive
Drawbacks: Requires frequent cleaning
Cost: Low to moderate ($30 to $400)

The simplest microhydro diversions are variations of a screen-covered pipe stuck in a creek. However, they require frequent cleaning. During the first rains of the season in some locations, twice-daily cleanings may be necessary to remove leaves and debris from the screen.

If placed in the stream's direct flow, the intake should be situated at least 1 foot underwater for pipe diameters up to 4 inches. This can create cleaning issues, especially during high-water periods. Although most folks aren't interested in wading into icy waters to clean their intakes, on small creeks these diversions can be reasonably nuisance-free most of the year, and the needed materials are inexpensive. The simple screen can be used in many different situations.

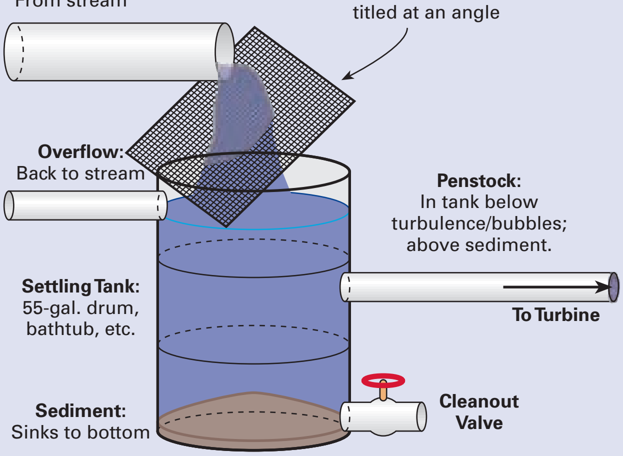


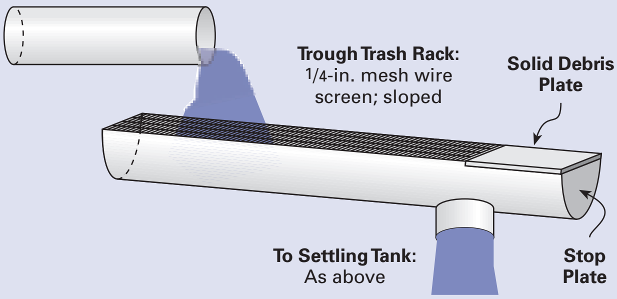
Open-Ended Pipe or Flume, with Settling Container

Benefits: Easy to clean; can be set up to filter out fine particles if needed; low maintenance
Drawbacks: Splashing and turbulence can cause air bubbles to enter the penstock; maintenance can be high if there are a lot of leaves
Cost: Low to moderate ($30 to $400)

The next simplest diversion is an open pipe or flume that feeds a large vessel, such as a bathtub, 55-gallon drum, or cistern. This approach offers easier access for cleaning than the pipe-with-screen method above. A 1/4-inch wire-mesh screen is secured over the container to catch larger debris. If needed, a finer mesh can be used under the 1/4-inch screen to catch smaller particles. A cleanout can be placed at the bottom of the vessel to remove the fine sediment that makes its way through the screen.

In my system, a bathtub is located under the spillway of a small dam. A disadvantage to this bathtub design is that above flows of 300 gpm, water coming over the spillway into the container tends to be turbulent and air bubbles can make their way into the penstock. This can result in lower turbine performance and also lead to early runner and bearing failure due to a water-hammer effect. Using a deeper container, like a 55-gallon drum, usually fixes this problem. Maintenance is still medium to high in the fall because of leaves but is less during the rest of the year. The bottom illustration shows a somewhat "self-cleaning" version.

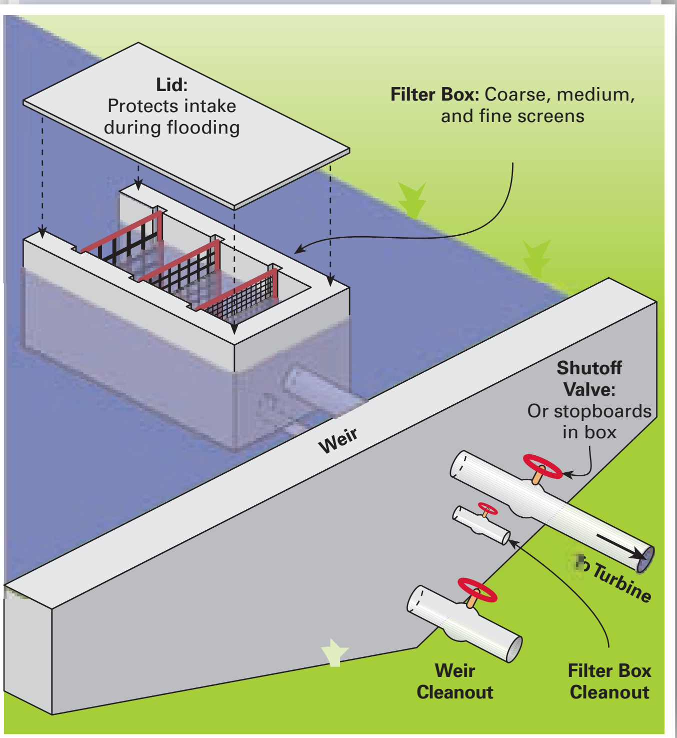




Screen Box

Benefits: Multiple screens catch debris of various sizes
Drawbacks: Moderately hard to clean because screens need to be removed from box
Cost: Moderate to high ($100+)

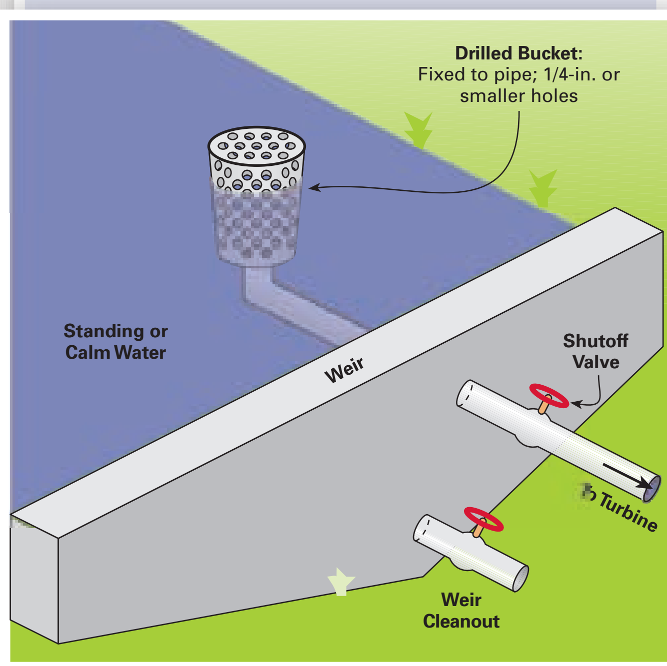
Screen boxes are the second-most common intake. They are generally constructed of concrete on-site, but can be fabricated of steel or plastic and brought in. Screen boxes are usually installed on the side of a small dam or slow-water area of a stream. They often have three screens, two valves, and a cleanout. These work about as well as the bathtub diversion, but appear less lowbrow. They are harder to clean, especially during high-water events when the water level may be above the top of the box. If constructed without an outlet shutoff, debris can enter the pipe when the screens are removed for cleaning, which defeats using the screen box in the first place.



Pond Bucket

Benefits: Simple to build
Drawbacks: Requires slow water with a stable level, plus access by boat or walkway; doesn't screen floating debris well
Cost: Low ($30 to $50)

Another common method—the pond bucket—can be used close to the bank of a pond or slow-moving stream that has a fairly stable water level. With this approach, a pipe is run underground or through the dam to a screen. In a pond, the screen is often a 5-gallon bucket with many holes drilled in the sides and top. Although this intake generally does its job in slow-moving and relatively clean water, large floating debris can strike the screen or bucket, dislodging it. And access to the intake for cleanout isn't very convenient: You'll either need a plank walkway or a boat—or be prepared to swim. This diversion strategy is popular in areas with a lot of beaver activity because their dams won't impact the diversion. Pond bucket intakes can tolerate some heavy flows in the source, since pond levels can be controlled to some extent most of the time.



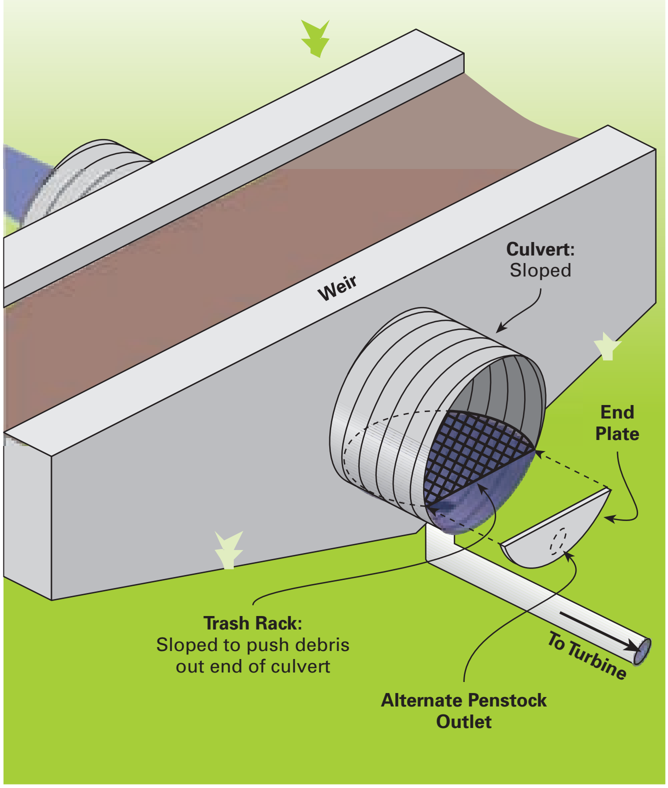
A diversion can be simple or elaborate, inexpensive or costly—but it needs to suit your application in a mechanical sense and also in an ecological one.

Culvert Tap

Benefits: Uses an existing culvert as a diversion
Drawbacks: Decreases capacity of culvert; can't accommodate higher flows easily; requires fabrication skills
Cost: Low to moderate ($30 to $400)

This strategy taps into the bottom of a sloping culvert pipe near its lower end with a pipe adaptor to the penstock. A screen, angled low in the culvert at its upstream edge, increases in height relative to the bottom of the culvert at about 3 inches per foot. Because the slope of the culvert is still steeper than the slope of the screen within it, water can wash debris over the screen, making it somewhat self-cleaning. A wedge-shaped block at the end of the culvert and screen maintains the water level above the penstock adaptor.

Although this is a simple solution, be careful cutting or welding galvanized pipe—the fumes are toxic. Also be mindful of the maximum volume of water the pipe needs to carry during flood season. If a road washes out, you will be responsible for the damage.



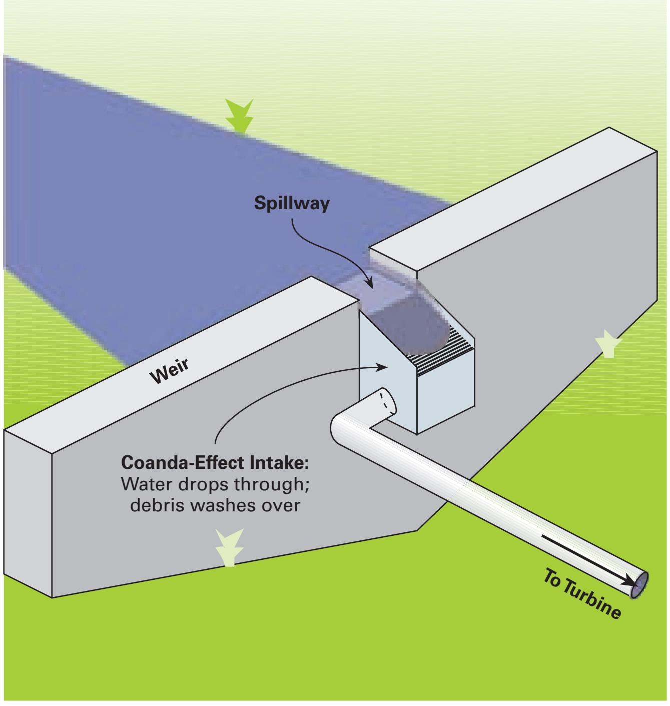
With the right circumstances, harnessing microhydro electricity is cheaper and more constant than either photovoltaic- or wind-powered electricity.

Spillway with Coanda-Effect Screen

Benefits: Self-cleaning; easy to install; minimal ecological impact
Drawbacks: Expensive hardware; requires spillway
Cost: Moderate to high ($900+)

If you can construct a spillway, a Coanda-effect shear screen, which uses the surface tension of water and triangular-shaped slots to suck water through without the debris (see *HP71*), can be an effective, nearly maintenance-free solution. In warm-water areas where algae tends to grow, it will be necessary to occasionally wipe off the screen.

Although a Coanda-effect screen is pricey, its stainless steel construction helps ensure its longevity—it should last forever, barring damage from trees or boulders. Many state agencies now require this type of screen for microhydro applications because of its minimal ecological impact—almost nothing makes it past the screen, including fish.

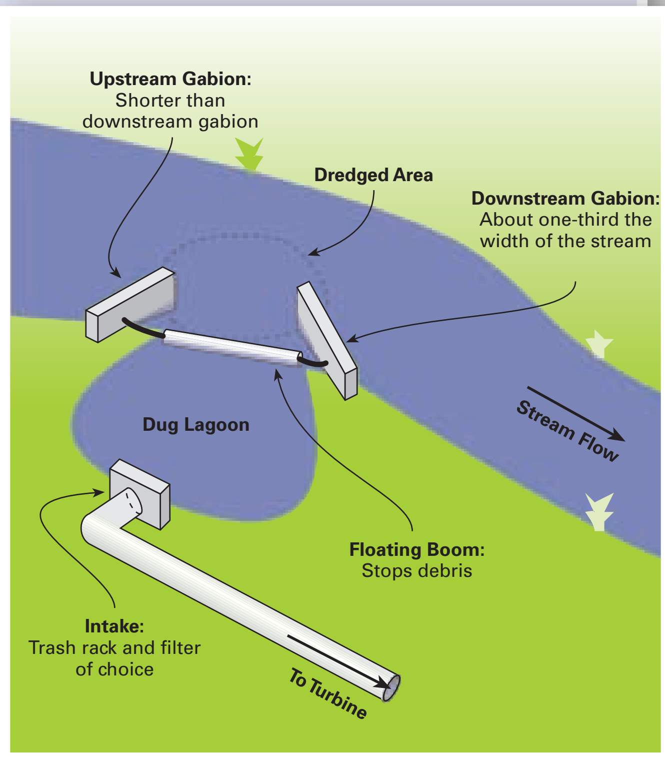


Slow-Water Zone Diversions

Benefits: Good for larger streams
Drawbacks: Complicated and time-consuming to build; potential for stream blowouts
Cost: High ($1,500+)

These diversions are normally used on larger streams or rivers because of their expense, but can be used on smaller ones as well. I have built diversions in dry areas next to the stream and slightly below the existing water level, usually using concrete lagoons. When completed, simply breach the side of the creek to fill the new mini-pond. The important thing is not to redirect the stream flow out of its banks but just to pull water from it. I know of one case where the installer breached the side of the creek and accidentally redirected the creek through a neighbor's house!

Gabion (a wire-mesh cage filled with rocks) weirs can be extended from the bank to deflect the main stream flow enough to create a slow-moving (0.5 foot per second) water area to help settle debris. The deflector can also be made with rock and mortar. Gabion cages can be purchased flat from most irrigation supply stores, then assembled and filled on-site.

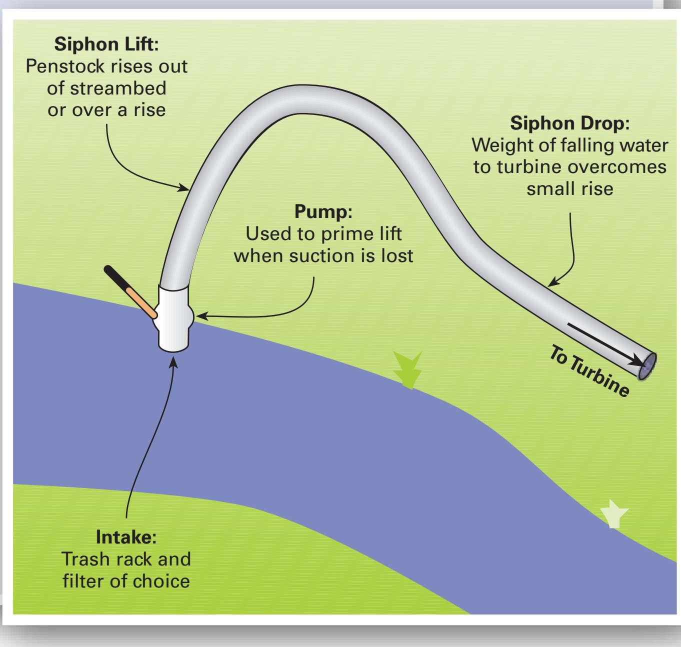


The important thing is not to redirect the stream flow out of its banks, but just to pull water from it.

Siphon Intake

Benefits: Simple to install
Drawbacks: Loses prime, so restarting is often needed; still needs screening
Cost: Low ($30 to $50)

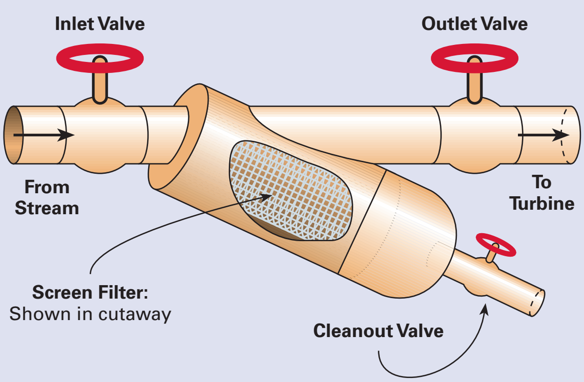
A siphon intake over a diversion works by pulling water up a short rise, using suction from the downhill-flowing pipe below it. This kind of setup can work fine for pumping water, but tends to lose the prime in a hydro application. Because of this tendency, these intakes require a foot valve and a priming process (usually a hand-operated pump) to replace the trapped air with water when suction is lost. They are used with a simple screen-type filter as part of the foot valve. Use this method if you must, but it is not advised—significant attention will be required, and you will eventually hate your microhydro system.



In-Line Canister Filter

Benefits: Ready-made to bolt in-line with the penstock; easy to clean
Drawbacks: May require prescreening of fish and other objects; expensive hardware
Cost: High ($1,500+)

In-line canister-type screens can work very well but still require prescreening to keep fish and larger objects out of the pipe. They usually have a cleanout port and bolt-up flanges for connection. I have used canisters made by Amiad Filtration Systems, but you should see what is available in your area in case you ever need parts. Water filters intended for households or drinking water will *not* work because they plug up too fast.



The Choice Is Yours

If you're lucky enough to have a creek that drops in elevation across your property, tapping into hydro-electricity is a great way to generate your own renewable energy. Properly installed systems will have minimal impact on the water source's ecosystem and its inhabitants. The range of intake and diversion types is as wide as a river. By reviewing the possibilities, you will find the right intake to fit your budget, the water source, and your personal availability for cleaning and maintaining the system.

Access

Jerry Ostermeier (altpower@grantspass.com) owns Alternative Power & Machine in Grants Pass, Oregon (541-476-8916; www.apmhydro.com). He has been designing and installing microhydro and off-grid power systems since 1979. He also manufactures a user-friendly, residential-scale microhydro turbine.

Intake Equipment Manufacturers:

Amiad Filtration Systems • www.amiadusa.com • In-line screens

Hydroscreen Co. LLC • www.hydroscreen.com • Coanda-effect screens

Low-Head Microhydro Thai Style

Above: The author and his family in Doi Inthanon, Chiang Mai Province, Thailand.

Left: This AC-direct microhydro system provides a source of renewable electricity for a community training center.

For the past several years, Chris Greacen has been living in Bangkok, Thailand, with his wife Chom and their two children, 5-year-old Ty and 3-year-old Isara. He and Chom run a small, nonprofit organization called Palang Thai. ("Palang" means energy or empowerment. "Thai" means freedom or independence.) Through policy and hands-on activities, the organization works to improve governance in the region's energy sector, and to increase the use of renewable energy in Thailand and the Mekong region of Southeast Asia. They've enjoyed several victories in their tenure: drafting Thailand's net metering regulations, helping to shape legislation that establishes an independent energy regulator, and installing solar-electric systems for medical clinics in war-torn areas of Burma (see "Solar Lights for a Dark Time in Burma" in *HP113*). Here Chris writes about one of their most recent projects: the installation of a low-head microhydro system in northern Thailand.

Story & photos by Chris Greacen

Last summer, while my family and I were visiting Doi Inthanon National Park in northern Thailand, we spent some time in Mae Klang Luang—a hill-tribe village about 12 miles inside the park. Though the 200-year-old village only recently opened its doors to tourists, it has quickly become a sought-after destination for its cultural and ecological allure. The village sits in the shadow of Doi Inthanon, Thailand's tallest mountain—among the easternmost beginnings of the Himalayas. The villagers are members of the Karen ethnic minority who migrated to the Thai/Burma area centuries ago from Mongolia. Though the village is very traditional in most ways—the people still harvest and thresh rice by hand—the electric grid was brought into Mae Klang Luang in 2007. Even with utility electricity on hand, some of the villagers still prefer energy independence—tapping the watershed's abundant streams and rivers to generate their own electricity.

Below: Local lumber, rocks, sandbags, and bamboo were used to construct the weir and waterway.

Above: The 6.5-foot-long draft tube is attached to the trough.

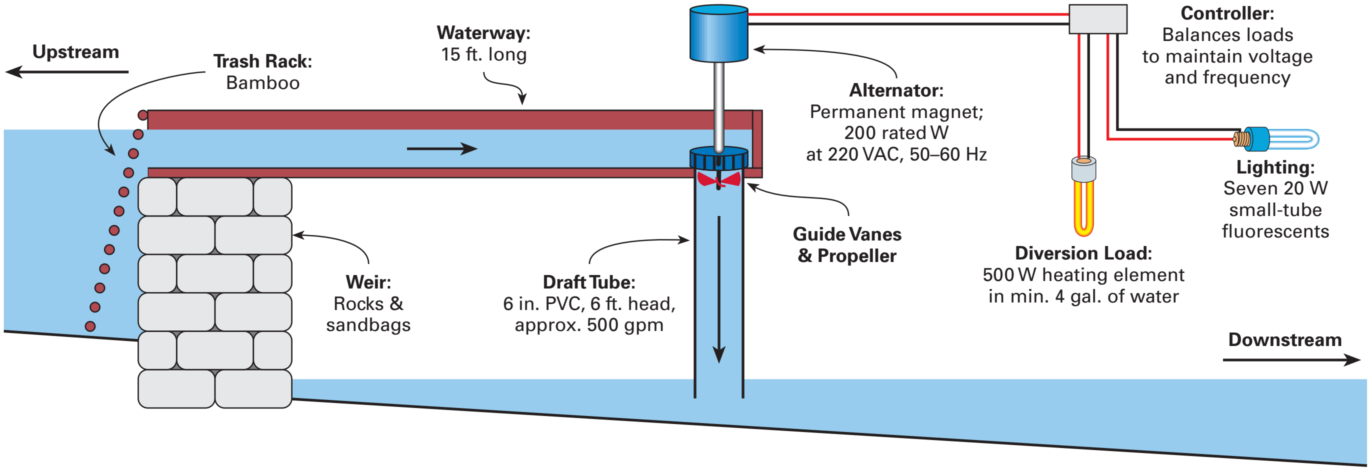
We ended up in Mae Klang Luang after a friend told me about a homestay program that would allow us to live with a local family for a few days. Chom and I liked the idea of supporting the community while exposing our children to the Karen way of life. When we finally arrived in the village, after a two-hour car ride along winding roads, we were surprised to find a film production crew, complete with police barricades, setting up to film a documentary that involved a member of the Thai royal family. An overzealous policeman told us that we could not stay in the village and we would have to turn back. Luckily, a local man, admittedly upset by the policeman's readiness to turn away tourism dollars, overheard the conversation and intervened. Our new friend introduced himself as Somsak Khiriphumthong and directed us down the road to a host home.

Later that evening, I met up with Somsak at a bamboo shed where community members gather to roast, grind, and drink locally produced organic coffee. I came to learn that Somsak runs a training center that teaches local people about the importance of organic farming, environmental preservation, and watershed management. His mission, as he explained, is to promote ecologically sound microenterprise while still preserving the cultural traditions of his people. Somewhere between our first and second cups of coffee, the topic shifted to renewable energy and my work with Palang Thai.

Somsak admitted that he had reluctantly brought grid electricity to the training center from the Provincial Electricity Authority (PEA), Thailand's rural distribution company. Initially he had resisted using PEA because of his concern for the environment. "Trees have to be cut down to get the power poles in, and PEA electricity comes from Thailand's mineral resources, like coal," says Somsak. "When they take coal from the mountains, they destroy them, and the air too. Plus, PEA power means paying a bill every month."

Even with grid electricity now on site, Somsak was still interested in using a nearby stream to generate electricity to power some of the center's loads. Somsak said that he had tried his hand at hydro-electricity several years ago, and rehashed one failed attempt that involved a makeshift Pelton turbine he made from a bicycle wheel and an automotive alternator. After talking some more about the water resource at the center, I said, "Well, I know of a turbine that I can bring up. Let's do it."

AC-Direct $100 Microhydro System



Above: Somsak puts the final touches on the trough.

A close-up of the turbine's propeller and guide vanes (left), and controller and turbine windings (below).

Back for the Installation

In November, I made my way back to Mae Klang Luang with a $90 Vietnamese-manufactured, low-head hydro turbine in hand. While the use of these turbines is still fairly uncommon in this region, they are popular with the few locals who already use them, primarily due to the units' low cost. The fact that the technology is pretty straightforward is attractive too. There are few parts, worn-out bearings can be easily replaced, and the weir and waterway that deliver water to the turbine can be inexpensively built using local lumber, rocks, sandbags, and bamboo.

The turbine I purchased for Somsak's installation came equipped with a guide vane and propeller assembly, a 2-foot-long enclosed shaft, and a permanent-magnet, 220-volt (nominal) AC alternator. The $90 price tag also included a small voltage controller. The turbine/controller combination is designed to power AC loads directly, without any kind of battery storage in the system. If the combined household electric load is insufficient, the controller's simple transistor circuit drives a silicon-controlled rectifier (SCR) to maintain a constant load on the turbine by diverting excess electricity to a resistive submersible heating element. This control method regulates the turbine's AC voltage.

Prior to my arrival, Somsak and his friends had built a small support for the turbine's trough (waterway) from scrap wood and bamboo. The support, which needed to be strong enough to support the weight of the trough, turbine, and several hundred pounds of water, was positioned near a small stream that runs year-round by the training center. At this location, the streambed dropped about 6 feet over a 15-foot span.

When I arrived in Mae Klang Luang, we immediately got to work building a 15-foot-long waterway in two sections, using lumber and bamboo that was on hand. Much of the work was done with a multitool and a machete—though we grabbed hammers, wire cutters, and screwdrivers as needed. We cut a 6-inch-diameter hole for the turbine in the bottom of one end of the trough and wrapped the end with a rounded section of galvanized sheet metal.

Microhydro for $100?

On your next visit to Southeast Asia, you may want to forego the traditional souvenirs, and take home one or two $100 microhydro units instead. Southeast Asia's best-kept secret weighs about 44 pounds (usually below airline baggage-weight limits), packs into a small box, fits into carry-on luggage, and can be found at markets in most major cities. In the Laos capital of Vietiane, for example, you'll have your pick of $100 microhydro units at the metal market. (Tip: Ask for directions to *talart lek*.)

When shopping for a system to bring back to the United States, be mindful of the voltage. If it is impossible to find a 120-volt turbine, you can still make the system work in the United States by using a 120/240 VAC transformer—also widely available in Southeast Asia. If transmission distance is significant, install the transformer close to the load and benefit from reduced resistive losses from high voltage transmission. The frequency produced by the turbine depends on the load and the water flow, and the turbine seems to have no problem operating at 60 Hz as well as 50 Hz.

If you're not heading to Asia anytime soon, you can order Vietnamese-manufactured turbines via PowerPal, a Canadian importer. For a more local product, check out the turbines manufactured by the crew at Energy Systems and Design in New Brunswick, Canada. Their low-head turbines feature a mechanical design similar to the Vietnamese turbines, but they are built for battery charging stations.

The Lowdown on Low-Head Hydro

Most of the microhydro turbines used in home-scale installations in the United States use either a Pelton- or Turgo-style runner coupled to an AC permanent-magnet alternator. These types of turbines are typically used at sites where the vertical drop is more than 15 feet. Water enters a screened intake at the top of a pipeline that runs downhill along the stream's course. There is 1 psi of pressure for every 2.31 feet of drop in the penstock's elevation. The resulting column of pressurized water above the turbine is routed through one or more nozzles inside the turbine's housing, creating strong jets of water that are directed at the turbine's runner to spin the alternator, which generates electricity.

In the Vietnamese low-head hydro unit that I purchased for Somsak's installation, the physics is reversed. There is no penstock. Water is diverted from a stream and channeled through an open-top, elevated waterway that delivers water to the turbine. Instead of the penstock, a pipe called a draft tube is installed *below* the turbine. The draft tube sucks water through the propeller, which in turn spins the alternator. This particular turbine design can generate electricity at sites with as little as 5 feet of head so long as a sufficient flow rate is available. Because of this low head requirement, these turbines are frequently installed between terraces in the rice fields in Southeast Asia.

Unlike the output in many other systems, which either charge batteries or are grid-connected, the voltage of the Vietnamese turbines' AC output is regulated and fed directly to AC loads, most commonly lighting. The inexpensive turbine's AC output is not designed to be synchronized with the utility grid. While the power quality regulation is pretty sloppy—probably not something you'd want to subject your home entertainment system to—it's definitely sufficient to power lighting and other simple appliances typically used in remote parts of Asia.

Once the waterway was fastened to the bamboo support structure, we secured the bottom of the turbine in the trough and then fit the draft tube—6.5 feet of 6-inch PVC pipe—to the base of the trough. We positioned the pipe slightly above the streambed but still submersed in the pool below so that the water discharge from the draft tube was unobstructed.

The wiring of the project was pretty simple. We ran 150 feet of cable from the turbine to the controller, which we mounted inside one of the center's buildings. We installed the diversion-heating element in a 20-gallon bucket of water located under the building to keep it away from the village children. I made sure Somsak understood it was imperative to keep the diversion load submerged to prevent it from burning out.

Up & Running

After everything was installed, we went over the hydro setup one last time, double-checking the wiring and installation details. Once we determined that everything was good to go, we opened the intake in the stream, watched the trough fill with water, and listened as the hydro turbine spun.

Along with the turbine's whirring, a loud sucking sound caught our attention. Through trial and error, we discovered that a bad seal between the draft tube and the trough was affecting the turbine's output. Somsak disappeared for a bit and miraculously, considering our remote location, came back with a sheet of firm synthetic sponge material used to make the soles of sandals, the locals' preferred footwear. We cut a gasket from the material, fit it between the trough and draft tube, and just like that, the turbine's output jumped to 0.7 amps at 220 VAC—154 watts—from about 500 gallons per minute of water falling only 6 feet.

I did a little more geeking with my digital multimeter and noticed that the turbine's voltage controller seemed to produce a waveform with considerable harmonics. At one point, my meter, obviously reading the third harmonic, indicated a frequency of 155 hertz. This "dirty" waveform really wasn't very surprising. The control unit operates by slicing part of the alternator's sine wave to send to the diversion load, which means that only a sliced portion of the waveform is going to the appliances. For lighting, fluorescent bulbs with the old-fashioned magnetic ballasts seem to be more tolerant of the turbine's low power quality than compact fluorescents (CFs) with electronic ballasts.

Power quality aside, our hydro installation was both fun and successful, and Somsak was delighted to have a functioning hydro system at the education center. The turbine powers fluorescent lights in several buildings and the occasional small appliance, like a radio or CD player.

Chris and Somsak assemble the waterway.

The completed installation: weir, waterway, and turbine.

Low Head & Low Cost

Reportedly, 100,000 low-head hydro turbines have been installed in rural Vietnam. And every one of these turbines creates more interest in utilizing local hydro resources to generate renewable electricity at remote sites beyond the reach of the utility grid. In Somsak's case, even though utility power was available, he opted to produce his own electricity, independently—further proving that the call for clean, independent energy is not only heard across the United States, but also in the remote villages in Thailand, and everywhere in between.

Access

Chris Greacen (chris@palangthai.org; www.palangthai.org) and his family will move stateside this spring. Thanks to a long-term lease from the Lopez Community Land Trust, the family will build a net zero energy, solar-powered home on Lopez Island in Washington's Puget Sound.

Web Extra: Video of this project can be viewed at: www.youtube.com/profile_videos?user=cgreacen

Center for Water Resources Conservation & Development • info@warecod.org • www.warecod.org • Vietnamese low-head turbines

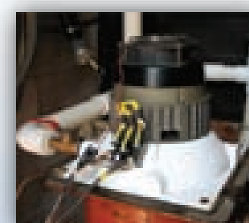
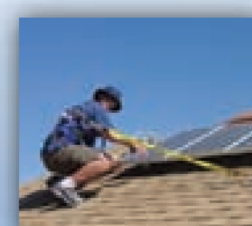
Energy Systems & Design • www.microhydropower.com • Canadian low-head turbine manufacturer

PowerPal • www.powerpal.com • Canadian importer of Vietnamese low-head turbines







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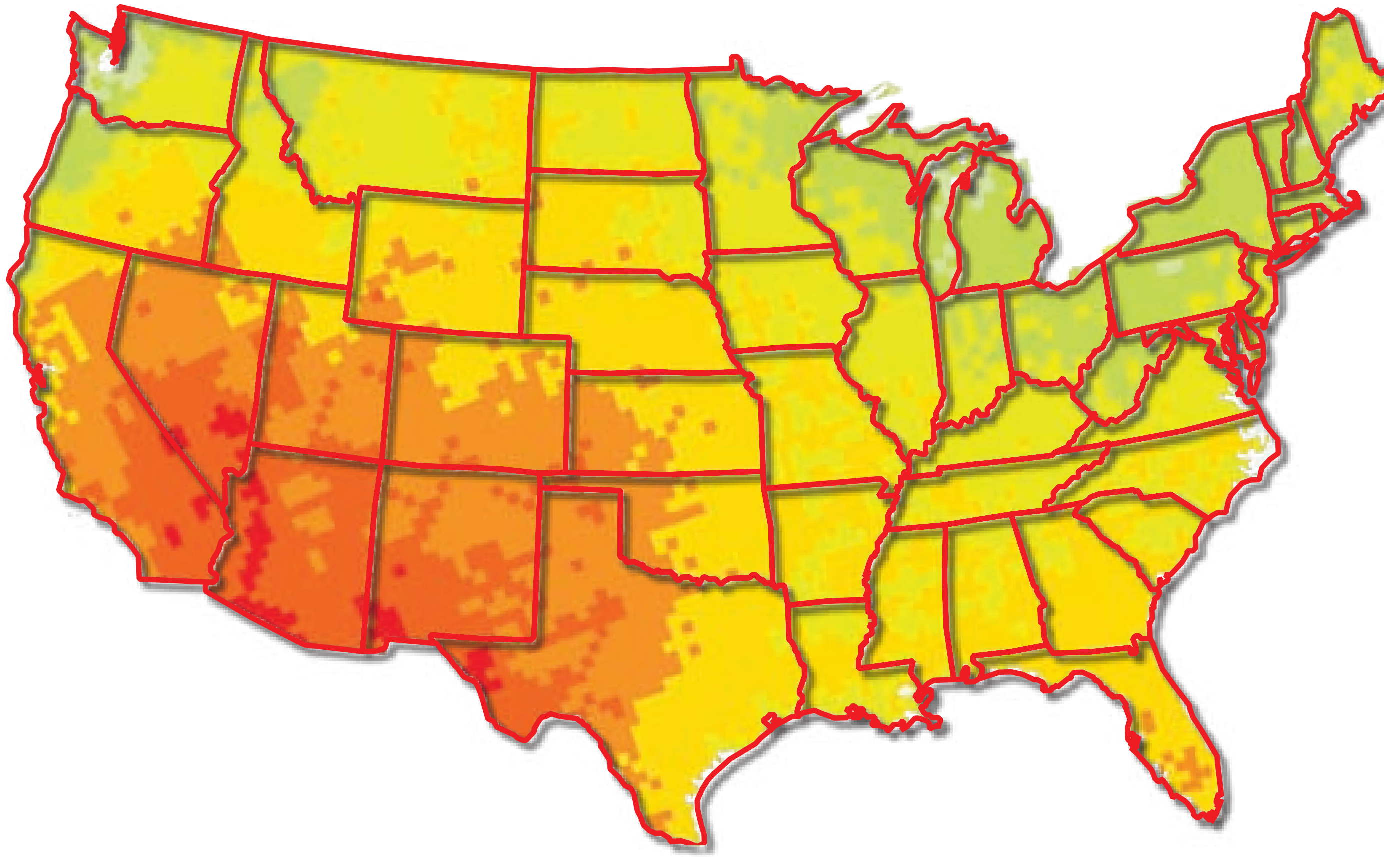
The Best States FOR SOLAR

by Kelly Davidson



What does it take to make it on our list of top solar states? Strong incentives, forward-thinking regulatory policies, and aggressive renewable energy goals are a good start. But what really gets the *Home Power* crew excited is any state that takes serious steps from a fossil fuel-based economy to a solar-based one.

To compile our listing of the best states for solar energy, we turned to the Database of State Incentives for Renewables & Efficiency (DSIRE). We reviewed the financial incentives and regulatory policies in each of the 50 states. We talked among ourselves and checked in with solar energy experts for their opinions. When all was said and done, the following states got our nod for adding or increasing incentives for solar systems, and adopting regulatory policies that foster a renewable energy future. Some of our picks are obvious; others may surprise you. But each shines for its past, present, and planned strides in solar energy adoption.

Editors' note: States are listed in alphabetical order. Because RE policy is constantly and quickly evolving, some information presented here may have changed. For the most current information, contact the relevant office for each state's program, or visit the DSIRE Web site (www.dsireusa.org).

California

Population: 36,457,549

Latitude: 32°32′ N to 42° N

Average statewide daily peak sun-hours: 5.6

After a hot-and-cold relationship with solar energy for nearly three decades, California has stepped up its game. The Golden State is the leading producer of solar technologies in the United States and also has one of the largest solar markets in the world. From 1981 through 2007, California residents and businesses installed 200 megawatts (MW) of grid-connected PV capacity. The greatest push came in the mid-1990s when a series of historic state laws deregulated the state's investor-owned electric utilities, and set up incentives for grid-tied PV systems under the California Energy Commission's Renewable Energy Program and the Emerging Renewables Program. Effective January 2007, the state adopted a $3.3 billion, ten-year program, dubbed the California Solar Initiative (CSI). The initiative has three program components, including a California Public Utilities Commission (CPUC) program that directs $2.167 billion in incentives to customers in investor-owned utility (IOU) territories.

Power position: As part of Governor Arnold Schwarzenegger's energy agenda, California set a goal to commission 3,000 MW of new PV capacity by 2017. The $400 million New Solar Homes Partnership—part of the CSI—aims to put solar-electric systems on 50% of all new homes by 2020.

Solar gain: In addition to new-construction incentives for developers, the CSI provides incentives for nonresidential projects and projects for existing homes. The program funds grid-connected PV systems through performance-based and "expected performance-based" incentives, which vary by utility territory, sector, and system size. For residential and commercial systems less than 100 kilowatts (KW), the "expected performance-based" buy-down ranges between $1.50 and $2.50 per watt AC.

Net metering: For systems up to 1 MW, net excess generation (NEG) is carried forward on a customer's next bill for twelve months. Any year-end excess goes to the customer's utility.

Shining moment: In 1983, California's Carrizo Plain became home to what was then the world's largest PV system—6 MW—which was constructed by Arco Solar and connected to the Pacific Gas & Electric Company utility grid. The effort soon failed due to poor engineering. The project's 100,000 modules were sold to the public, ironically bolstering the off-grid solar movement that created the foundation for today's PV industry.

On the horizon: The CPUC has approved more than 1,400 MW of utility-scale solar facilities that should be online by 2015. In addition, the state's three largest IOUs are currently negotiating more than 7,000 MW of additional solar capacity.

Info: www.gosolarcalifornia.ca.gov

Colorado

Population: 4,753,377

Latitude: 37° N to 41 N°

Average statewide daily peak sun-hours: 5.8

Colorado is a gold mine of solar energy, boasting more than 300 days of blue sky per year. And the Rocky Mountain state is tapping its resources. In addition to legislation that authorizes counties and municipalities to offer rebates, loans, and property and sales tax exemptions for PV systems, the state has adopted aggressive policies that encourage the development of solar technologies and PV manufacturing plants. Colorado is home to the U.S. Department of Energy's National Renewable Energy Laboratory, as well as one of the largest solar power plants in the United States—an 8.22 MW plant made possible by a power purchase agreement between SunEdison and Xcel Energy.

Power position: In 2007, Governor Bill Ritter enacted legislation that increased the state's renewable portfolio standard from 10% by 2015 to 20% by 2020. According to the new legislation, large investor-owned utilities must obtain 20% of their electricity from renewable energy sources by 2020, while municipal utilities and electric cooperatives must achieve 10% by 2020.

Solar gain: Incentive programs for grid-tied residential and commercial systems are administered at the local level by individual cities and counties. Incentive rates vary, but the law requires that utilities offer customers net metering and a one-time minimum rebate of $2 per watt of installed PV capacity. Some communities, like Gunnison County, offer low-interest loan programs as well. The state's largest program, Xcel Energy's Solar Rewards Program, has paid out $19.5 million to more than 1,000 customers.

Net metering: Utilities that serve 40,000 or more customers must offer net metering for systems up to 2 MW in capacity. Net excess generation is applied as a credit each month. Any surplus at the end of a year is paid at the utility's average hourly incremental cost. Smaller cooperatives, including Empire Electric Association, offer net metering for systems up to 10 KW, but only to the first 50 customers who enroll before December 31, 2010.

Shining moment: In 2004, Colorado became the first state in the country to adopt a statewide RPS by popular vote rather than through the state legislature.

On the horizon: Xcel Energy has proposed the development of a utility-scale 200 MW solar power plant in Colorado before 2016—among the first of its kind in the nation. Future state legislation could bring retail rates for net metering, as well as a financing program that offers low-interest loans for residential and commercial systems.

Info: www.xcelenergy.com/solar; www.colorado.gov/energy

Connecticut

Population: 3,504,809

Latitude: 40°58′ N to 42°03′ N

Average statewide daily peak sun-hours: 4.4

Latitude, cloud cover, and air pollution may work against Connecticut, but that hasn't slowed the state's inclination for solar power. The ratepayer-funded Connecticut Clean Energy Fund (CCEF) is the main source of the state's solar incentives. Besides offering rebates for residential and nonprofit PV systems, the fund supports solar R&D projects and grants to buy down the costs of renewable energy systems. As of December 2007, the rebate program had issued approximately $6.15 million in incentives for smaller systems, representing slightly more than 1.4 MW of solar capacity.

Power position: Connecticut's renewable portfolio standard requires that 7% of the state's electricity comes from RE by 2010, and 27% by 2020. The state's initial RPS was enacted in 1998, but it took several amendments to close counterproductive loopholes and establish effective goals.

Solar gain: For residential systems less than 10 KW, the rebate is $5 per watt for the first 5 KW and $4.30 per watt thereafter. A grant program (with a budget of $74.5 million for various RE technologies, including $22 million left over from previous years) awards incentives for systems that generate electricity at commercial, industrial, and institutional buildings. The maximum grant is $2.5 million per PV project. Property, use, and sales tax exemptions apply to residential, commercial, and industrial PV systems, as well as passive or active solar heating systems.

Net metering: In 2007, the state legislature expanded the net metering law to cover all customers with generation capacities up to 2 MW. Net excess generation is credited to customers' bills at the retail rate. At the end of a twelve-month billing cycle, any "excess" is purchased by the utility at its avoided-cost rate.

Shining moment: Thanks in part to a grant from CCEF, Dayville, Connecticut, is home to one of the largest PV installations in New England—a 550 KW system at a distribution center for United Natural Foods. The system, which went online in December 2007, is expected to generate up to 600,000 KWH of clean energy annually.

On the horizon: In June 2007, the Connecticut General Assembly voted to restore $95 million in funds that were diverted in 2003 from the CCEF and the Connecticut Energy Efficiency Fund by an emergency spending bill. Governor Jodi Rell immediately vetoed the line item because of a "constitutional spending cap." Legislation passed last fall authorizes restoration on some level by the end of the fiscal year (June 30, 2008), though the details are still being worked out.

Info: www.ctcleanenergy.com

Maryland

Population: 5,615,727

Latitude: 37°53′ N to 39°43′ N

Average statewide daily peak sun-hours: 4.6

With strong incentives and regulatory policies, Maryland is trying to set an example and inspire its lackluster neighbors—especially the Washington-based politicians across the way—to step up renewable energy efforts. Since 2005, the Maryland Energy Administration has administered a grant program that offers rebates for solar water heating and PV systems—mainly residential-scale. The number of grants has grown from an average of 37 per year in the first two years to more than 150 in 2007. In its first three years, the program supported 227 projects, including more than 100 PV systems for a total installed capacity of about 1 MW.

Power position: The state legislature revised the original renewable portfolio standard in 2007 to increase the use of solar energy. Electricity suppliers must derive 2% of electricity sales from solar generation by 2022, starting at 0.005% in 2008 and increasing each year. The aim is to have approximately 1,500 MW of solar capacity in Maryland by 2022.

Solar gain: The 2008 budget allocates $675,000 for rebates toward solar and geothermal systems. For residential PV, the program covers 20% of system costs, up to a maximum of $3,000; for nonresidential PV systems, 20% of system costs up to $5,000; for solar hot water systems, 20% of system costs up to $2,000. There is also a personal tax credit of $0.0085 per KWH for individuals or corporations—in addition to a 100% state property tax exemption for residential PV and solar hot water systems. Though legislation allows counties to offer local property tax exemptions to various sectors, only a few counties offer such credits.

Net metering: A net metering law has been in effect in Maryland since 1997. The current version of the statute allows net metering for systems up to 2 MW. Accrual of credits is for a twelve-month period, with remaining credits at the end of a twelve-month billing cycle purchased by the utility at its avoided-cost rate. Limit on overall enrollment is now set at 1,500 MW.

Shining moment: Maryland was the first state in the country to sign on to the federal Million Solar Roofs Initiative, introduced by President Bill Clinton in 1997.

On the horizon: Proposed legislation would increase grant amounts provided under the Maryland Solar Energy Grant Program. A sales-tax exemption for PV systems and equipment may be coming soon.

Info: www.energy.state.md.us

Massachusetts

Population: 6,437,193

Latitude: 41°14′ N to 42°53′ N

Average statewide daily peak sun-hours: 4.6

Even in the heart of New England, where overcast days outnumber the sunny ones, Massachusetts has adopted strong incentives and regulatory polices for solar energy. A new state-funded program, Commonwealth Solar, allocates $68 million over the next four years to offset the costs of residential and commercial PV systems. A portion of the budget is earmarked for schools and government buildings. This latest initiative follows five years of solar incentives offered by the Renewable Energy Trust, which helped develop 700 systems representing 5 MW of capacity. An additional 200 installations, totaling 1.5 MW, are in the pipeline.

Power position: In 2007, Governor Deval Patrick announced a plan to have 250 MW of PV systems installed by 2017, with 27 MW targeted for the first four years of the new Commonwealth Solar program. Under the state's existing renewable portfolio standard, PV system owners also receive payments for renewable energy certificates.

Solar gain: Administered by the Massachusetts Renewable Energy Trust and the Division of Energy Resources, the Commonwealth Solar program offers rebates that can defray 30% to 50% of the costs for eligible commercial systems and 20% to 60% of the costs for residential systems. The program also provides special incentives for Massachusetts-made PV modules and inverters.

Net metering: The state's Department of Public Utilities established net metering rules in 1982. Under current regulations, net excess generation is carried forward to the next month's bill and credited at the average monthly market rate. Even though the law only requires investor-owned utilities to offer net metering, many municipal utilities do so voluntarily. Current rules limit individual system capacity to 60 KW, but pending energy legislation may increase the maximum to 2 MW.

Shining moment: Massachusetts-based Evergreen Solar Inc. is building its second and largest U.S. PV manufacturing plant in Devens, Massachusetts. The new $165 million facility, scheduled to open in late 2008, will increase the company's production capacity in the state by 70 MW and double its statewide employee base to more than 600.

On the horizon: After the initial four-year phase of the Commonwealth Solar program, the state is looking to transition to market-based renewable portfolio standard or feed-in tariff approaches to further enhance the growth of PV installations toward the 250 MW goal.

Info: www.masstech.org/solar

Empower Your State

When it comes to poor financial incentives and weak regulatory policies for renewables, these states are the *best* at being the *worst*: Alabama, Alaska, Mississippi, South Dakota, and Kansas, with Tennessee and Nebraska not far behind.

If you live in a state with poor or nonexistent policies for RE, it's easy to point a finger at your state legislators and throw up your hands in frustration. But most state or utility-wide RE programs have been built from the ground up by solar industry representatives, policy advocates, and end users who want to see a positive change in how electricity is generated. As the old saying goes, "If the people lead, the leaders will follow." Here's how you can encourage your state to do better.

Form, join, and support RE advocacy groups. Team up with a local group that's working on energy issues. If there isn't one, start one. Small groups of organized people can make big changes in state energy policies. A dozen or so people, for example, spearheaded the legislation that resulted in Oregon's net metering law.

Defy party lines. Support for renewables is constantly growing on both sides of the political aisle. The most successful RE campaigns garner support across party lines.

Build public support. Get people talking about renewables. Submit letters to the editor at local newspapers, launch a public blog, and join Web-based community groups. At every turn, take note of clean-energy supporters and keep a contact list.

Write your representative. It may sound like an old-school approach, but feedback from a large number of constituents can make all the difference in how a representative votes. When an important piece of legislation goes before your representative for a vote, break out your contact list and encourage people to write letters, make calls, and send e-mails.

Vote. Make your vote count. Before you head to the polls, take the time to research the candidates' voting records on energy issues. You may be surprised by what you find. *www.vote-smart.org*

Support the Solar Energy Industries Association. If you're an industry professional, your participation in both the national SEIA organization and state or regional SEIA chapters is crucial. SEIA's experience and influence has been instrumental in most RE policy and incentive efforts. *www.seia.org*

Be patient and persevere. It may take two or more years to bring successful RE incentive programs and legislation to fruition. Prepare yourself for a sustained effort.

Minnesota

Population: 5,231,106

Latitude: 43°30′ N to 49°23′ N

Average statewide daily peak sun-hours: 4.5

Minnesota may be the northernmost state outside of Alaska, but it has more annual solar energy potential than Houston, Texas, and nearly as much as Miami, Florida. Since June 2002, the Minnesota Department of Commerce has administered a rebate program that pays a portion of the up-front costs for grid-connected PV systems. After the initial $1 million budget from the Xcel Energy Renewable Development Fund was depleted in 2006, applicants were put on waiting lists until an additional $500,000 in funding became available in July 2007. As a result of the rebate program, the state has approximately 200 more PV systems, representing about 1 MW of installed solar capacity. The state is also home to hundreds of solar thermal systems—despite not offering incentives for solar thermal. All numbers aside, Minnesota's incentives, regulatory policies, and demonstrated commitment to solar energy are truly impressive for a high-latitude state.

Power position: In 2006, Governor Tim Pawlenty signed legislation that requires energy companies to provide 25% of their power from renewable sources by 2025. Xcel Energy, which supplies approximately half of the state's electricity, is required to provide 30% from RE by 2020.

Solar gain: The state's incentive programs compensate system owners $2 per rated watt, with a maximum rebate of $20,000 per system. Other utilities in the state support rebate programs that will match the state's rebate, up to $4,000. The state also offers sales-tax exemption for all PV system components, as well as property tax exemption for PV systems.

Net metering: Unlike most states that require leftover net excess generation be compensated at an avoided-cost rate, Minnesota requires each utility to compensate customers for NEG at the "average retail utility energy rate." All "qualifying facilities" up to 40 KW in capacity are eligible.

Shining moment: Minnesota was the first state to adopt net metering, doing so in 1981. Today, it is one of only two states in which customers receive a check for NEG at the end of each month, based on the average retail rate.

On the horizon: An additional $500,000 (plus any unused funds from 2007) will be available to offset the cost of residential, commercial, and nonprofit PV systems on July 1, 2008. The program will remain active until all funds are disbursed.

Info: www.xcelenergy.com/solar; www.commerce.state.mn.us

New Jersey

Population: 8,724,560

Latitude: 38°56′ N to 41°21′ N

Average statewide daily peak sun-hours: 4.6

New Jersey is one of the fastest-growing solar markets in the United States. It's the largest in terms of installations per capita and, in terms of installed capacity, second only to California, which has four times the population and energy usage. Since the New Jersey Clean Energy Program started in 2001, the number of installations from the program has grown from six to more than 2,400. But the program's success is a mixed blessing. An unprecedented surge in applications outpaced the $273 million budget allotted for rebates over the last three years, forcing the NJ Board of Public Utilities to reassess the program structure.

Power position: New Jersey's renewable portfolio standard requires that 22.5% of the state's retail electricity be derived from renewable sources by 2021, and 2.12% must come from solar.

Solar gain: The state is transitioning from a taxpayer-funded rebate program toward a performance-based financing model that relies on tradable Solar Renewable Energy Certificates (SRECs). As of early February, the pilot program has received applications for 124.7 MW of capacity and has approved 65.5 MW. System owners earn one SREC for every 1,000 KWH of solar-generated electricity. These credits can be sold to electricity providers to meet the renewable portfolio standard Rebates have not completely disappeared and will likely continue until 2012 for systems smaller than 10 KW—though the definition of "smaller" could change.

Net metering: New net metering rules are due by May 1, 2008. In the past, net excess generation was paid at the utility's full retail rate and carried over to the following month as a credit. At the end of an annualized period, the utility pays the customer for any remaining carryover at the utility's avoided-cost rate. The new rules will allow real-time hourly pricing.

Shining moment: Today, an impressive mix of homes, businesses, municipalities, and schools feature more than 50 MW of installed solar capacity—thanks to the state's original incentives and rebates that covered up to 50% of the initial system costs.

On the horizon: In 2006, the board established a "queue" for private-sector systems less than 10 KW and greater than 10 KW—representing more than $100 million in unfilled rebates for homes, businesses, and schools. In December 2007, the board suspended the acceptance of rebate applications and announced that those in the queue will receive rebates when funding becomes available. Plus, there's talk of a community-solar pilot program that would allow residents to invest in larger, more economical systems rather than install individual systems on their homes.

Info: www.njcleanenergy.com

New Mexico

Population: 1,954,599

Latitude: 31°20′ N to 37° N

Average statewide daily peak sun-hours: 6.2

Though second in the nation for solar potential, New Mexico has struggled to reach its full capacity. The state is now on track with an aggressive mix of renewable energy programs. While an average of 300 days of sunshine—350 in some areas—didn't hurt the cause, having a former Secretary of the Department of Energy for governor sure helped expedite the process. Key to the state's shining success is the Solar Tax Credit administered by the New Mexico Energy, Minerals, and Natural Resources Department. Other tax credits and exemptions position the "Land of Enchantment" as a sweet spot for solar industry.

Power position: The current renewable portfolio standard requires that investor-owned utilities generate 20% of all retail electricity from renewable sources by 2020. Rural electric cooperatives must meet 10% by 2020. The state will be issuing revenue bonds to finance infrastructure to distribute wind- and solar-generated electricity throughout the state.

Solar gain: Residents, agricultural enterprises, and small businesses can earn a tax credit of up to $9,000 for solar thermal and PV systems installed through 2015—with a maximum 30% recouped, less the current $2,000 federal tax credit. If two separate systems are installed, such as a PV system and a solar thermal system, system owners can claim state tax credits for both systems, up to $18,000.

Net metering: Monthly net excess generation of less than $50 is credited to the customer's next bill. NEG greater than $50 is purchased by the utility at its avoided-cost rate. New 2007 guidelines raised the maximum size for eligible net-metered systems from 10 KW to 80 MW.

Shining moment: With the 2005 passage of the $20 million Energy Efficiency and Renewable Energy Bonding Act, New Mexico's legislature became the first state to allow bond sales to fund solar and energy efficiency retrofits for schools and state buildings. In other RE news, the state has invested $10 million in New Mexico-based Advent Solar, a company that designs and manufactures photovoltaic cells and modules.

On the horizon: The Renewable Energy Transmission Authority Board aims to develop a system that would allow New Mexico to export RE-generated power to other states that need to meet their RPS. Schott Solar Inc. is investing $100 million into a new facility in Albuquerque that will manufacture PV modules, as well as equipment for concentrating solar thermal power plants.

Info: www.nmprc.state.nm.us

Oregon

Population: 3,700,758

Latitude: 42° N to 46°18′ N

Average statewide daily peak sun-hours: 4.4

Like its solar sister to the south, Oregon is taking steps toward becoming a leading PV market. Since 2003, the Energy Trust of Oregon has provided cash incentives for solar-electric and solar hot water systems to customers of Pacific Power and Portland General Electric (PGE). A combination of rebates, tax credits, and 100% property tax exemptions for industrial, commercial, and residential systems, as well as the passage of seven clean-energy bills in 2007, has made Oregon one of the best states in the country for solar. Oregon has attracted four manufacturers of PV components, and solar installations are increasing dramatically.

Power position: In 2007, Governor Ted Kulongoski urged the state legislature to adopt a renewable portfolio standard to require the largest utilities to supply 25% of their retail electricity with renewable sources by 2025. Smaller utilities will have similar, but lesser, obligations.

Solar gain: Incentives are based on system size and vary by utility. Homeowners can receive up to $10,000, for-profit businesses up to $125,000, and tax-exempt entities up to $225,000 for PV systems. For Pacific Power's residential customers, the incentive is $2 per watt, up to the maximum. The Oregon Department of Energy provides a personal income tax credit of $3 per watt, up to $6,000, and a business tax credit of 50% of installed system costs applied over five years.

Net metering: Oregon's municipal utilities, electric cooperatives, and people's utility districts are required to offer net metering. Separate, though similar, net-metering laws apply to Oregon's primary investor-owned utilities (PGE and PacifiCorp). Net excess generation is either purchased at the utility's avoided-cost rate or credited to the customer's next monthly bill. At the end of an annual period, any unused NEG credit is granted to customers enrolled in one of the state's low-income assistance programs. In 2007, the Oregon Public Utility Commission raised the net-metering system size limit for commercial systems from 25 KW to 2 MW. Residential systems are limited to 25 KW.

Shining moment: Thirty years ago, Oregon began encouraging the use of solar energy in buildings with a state tax credit. The University of Oregon's Solar Radiation Monitoring Laboratory is a national leader in providing more than twenty-five years of measured solar radiation data for the Pacific Northwest.

On the horizon: SolarWorld AG is moving its current production facilities from Vancouver, Washington, to Hillsboro, Oregon. The new $400 million facility will produce solar cells and wafers—with an annual output of 500 MW by 2009.

Info: www.oregon.gov/energy

Pennsylvania

Population: 12,440,621

Latitude: 39°43′ N to 42°16′ N

Average statewide daily peak sun-hours: 4.3

Pennsylvania gets a gold star for promoting RE jobs. Though financial incentives have been exhausted for years, the state has gone far beyond other states to attract solar-related companies. Since 2004, the state's Energy Harvest program has directed $26 million in grants and loans for 81 "alternative energy" projects and leveraged $66 million in private investments. The state's programs have resulted in less than 1 MW of installed solar capacity, but RE giant Epuron LLC is building a 3 MW PV power plant that is anticipated to generate 3,700 megawatt-hours of electricity annually.

Power position: Pennsylvania's alternative energy portfolio standard requires that alternative energy sources provide 18% of all energy sold by 2021, with a solar set-aside of 0.5% to create about 850 MW of solar capacity. The downside: Pennsylvania's "alternative energy" portfolio standard includes certain waste-coal technologies.

Solar gain: Pennsylvania Energy Development Authority (PEDA) grants and loans help support RE manufacturing and production businesses. Energy Harvest grants bolster projects that reduce the use of conventional energy sources and improve economic conditions. Solicitation for PEDA and Energy Harvest grants has closed but is expected to reopen in spring 2008. Though partially dependent on the state budget process, both programs have consistently offered a combined total of more than $15 million annually.

Net metering: Investor-owned utilities must offer net metering, but capacity limits vary by sector. NEG is credited at the utility's retail rate and carried over to the customer's next bill during a 12-month period.

Shining moment: In 2005, a 2.8 KW grid-tied, battery-based PV system was installed at the governor's residence.

On the horizon: Governor Edward Rendell is asking the General Assembly to pass an $850 million, ratepayer-funded Energy Independence Fund that is expected to create $3.5 billion in economic growth and 13,000 jobs. Approval would create rebates that would cover up to 50% of the cost of solar-electric systems installed on homes and small businesses.

Info: www.depweb.state.pa.us

Access

Home Power Associate Editor **Kelly Davidson** (kelly.davidson@homepower.com) currently divides her time between three of the top ten solar states—Colorado, New Jersey, and Maryland. Her heart now belongs to Colorado, but New Jersey's solar record makes her proud to have been born and raised a "Jersey girl."

SIMPLIFYING solar thermal

by Dan Gretsch

According to the U.S. Department of Energy, 47% of the average home's energy use is for heat—either domestic hot water or space heating. Using specially designed collectors, solar hot water (SHW) systems collect the sun's heat and store it in water. In turn, this stored energy is tapped for domestic uses like showers, laundry, dish washing, or even heating your home.

Courtesy www.solarhotusa.com

Investing in Solar Energy

Installing a solar hot water system represents one of the best renewable energy (RE) investments that the average homeowner can make. While wind and microhydro can have a lower cost per KWH equivalent of energy generated, only a small percentage of Americans live where they can install either of these technologies.

On the other hand, most home sites in the United States have at least some access to direct sunlight. Solar electricity—converting sunlight into electricity—is very popular. But compared to solar hot water collectors, photovoltaic modules are comparatively inefficient and expensive. The efficiency range for crystalline PV modules converting sunlight into electricity is about 12% to 19%, and recouping an investment in a grid-tied residential PV system, even with incentives, can take between ten and twenty years. In contrast, for domestic water heating applications, SHW collectors convert about 60% of the energy in sunlight into hot water, producing up to about six times more usable energy per dollar invested. In locations with favorable incentives, SHW systems can recoup their costs in about three to seven years.

Even without any available financial incentives, a professionally installed SHW system with 64 square feet of collector area can produce the equivalent of about 20 KWH per day at an installed cost of $5,000 to $8,000. If you wanted to generate that amount of energy with PV, a system size in the range of 3.5 KW would be required, costing approximately $35,000.

Despite the obvious advantages, there has only been a modest increase in the number of SHW installations over the last several years compared to the significant growth in installed PV systems. With rising fuel costs and increasing interest in reducing carbon emissions, economic interests alone should be driving more significant growth in the solar thermal market than we are seeing. So what's the holdup?

Solar Hot Water Simplified

Solar hot water system installers are faced with myriad engineering decisions. Every home is different, and the optimal system type depends on a wide range of variables, including

the number of people in the home, how efficiently water is used in the household, the average daily peak sun-hours available at the site, potential shading from nearby trees or buildings, wintertime ambient temperatures, and the location and space available for collectors and hot water storage.

Once the optimal system type—open loop, drainback, or glycol—is chosen, the installer needs to determine collector type (flat plate or evacuated tube), collector sizing, flow rates, pump performance, heat exchanger sizing, valve type, wiring, mounting, equipment sourcing—and decide how to integrate all the components together. Despite comparatively modest system costs compared to PV, technically complex system design and installation is one reason that many potential installers shy away from the SHW field.

Three common product packages in the European SHW market have rapidly streamlined solar thermal installations overseas and are gaining popularity in the United States.

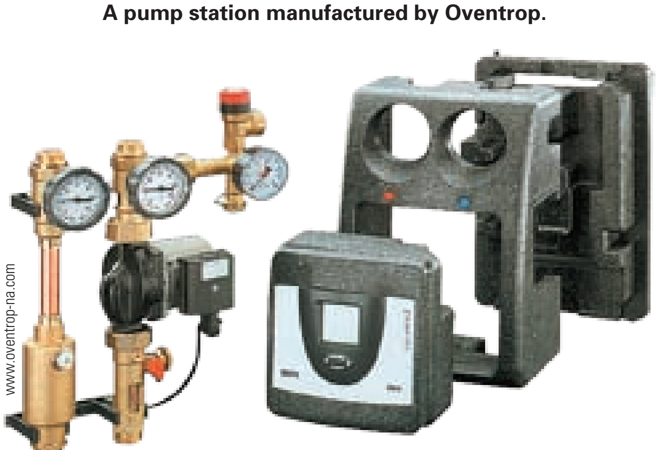
- Component packages
- Pre-assembled pump stations
- Integrated pump and heat exchanger units

The goal of each approach is to simplify system design, planning, and engineering, and to minimize system installation time and complexity.

Component Packages

To ease the burden of sourcing all of the different components required for an SHW installation, several companies offer packages of unassembled components. This eliminates some sourcing headaches but doesn't necessarily address the range of complex engineering issues that installers face. For example, as a situation dictates, you may need a larger heat exchanger or a different pump capacity. And, once you have addressed the design issues, you still have to assemble all of the individual components. A typical component package contains:

- Solar collectors
- Storage tank with heat exchanger
- Differential temperature controller
- Fluid circulation components
- Circulation pumps
- Installation manual
- Mounting hardware



A pump station manufactured by Oventrop.

The Solarnetix pump station. The front insulation is removed to show the components.

While component packages reduce the time required to source individual system parts from various manufacturers or suppliers, unassembled packages rarely reduce the installation time. With all of the individual components in hand, it will still take an experienced crew of two to three people two full days to assemble and install a system. Knowledgeable do-it-yourselfers will probably require twice that time. Unlike pros, they won't have a van or truck stocked with extra fittings, and will usually have to make multiple trips to the hardware store for elbows, couplings, and the like that aren't included in packaged systems but are necessary for site-specific installation. Then comes dry-fitting the pieces, making connections, pressure checking, repairing any leaks, rechecking pressure, and then starting up the system.

While unassembled component packages give the system installer a leg up, solutions with greater pre-integration and preassembly are available that can significantly reduce installation time and complexity.

Pump Stations

Pump stations were relatively common in the U.S. solar thermal industry in the 1980s, but virtually disappeared until several years ago, when companies in Europe began offering integrated pump packages (also referred to as circulation stations) for use with specialty heat-exchange tanks. This approach was a giant step toward reducing the complexity of an installation. With a variety of insulated, pre-plumbed components, these systems reduce the time required for the sourcing, connecting, and pressure-checking steps of an installation.

Pump stations do reduce installation time and complexity, but they don't cover all of the bases. Some stations include controls; others do not. Most are designed to integrate with specialized storage tanks with an integral heat exchanger. The cost of these specialty tanks alone can run $600 more (plus shipping) than a standard, locally purchased hot water tank.

Courtesy www.enerworks.com

EnerWorks manufactures integrated pump, control, heat exchanger, and storage tank systems.

Pre-Packaged Pump & Heat Exchangers

Pre-packaged systems—which integrate heat exchangers into the pump packages—work with standard hot water tanks. They include heat exchangers, pumps, isolation valves, controls, system drains, pressure relief valves, fill valves, pressure gauges, and check valves, all in a single package. Many are compact in design, which enables easy installation in relatively tight places. Each comes with virtually all of the special plumbing components pre-assembled to facilitate on-site installation.

While all of the available integrated systems work, the buyer still needs to pay careful attention to their suitability for a particular situation, including cost. Every system, integrated or not, has to address the questions of flow through the collectors and the transfer of heat to the storage tank. For example, some systems rely on thermosyphoning, convection that circulates liquid without requiring a pump. In these systems, although the cost and complexity are reduced, the slower flow reduces overall system performance. Different manufacturers also use different-sized heat exchangers. Systems that use smaller-capacity heat exchangers will be cheaper, but those that use larger exchangers will allow pumps to run less for the same amount of heat exchange. The size and type of pumps also influence system performance and cost—smaller pumps keep system costs lower but also reduce the flow and efficiency of the heat transfer. Cast-iron pumps are less expensive, but corrode sooner than bronze pumps when subjected to degraded glycol or dissolved oxygen that is present in the heat-transfer fluid.

Comparative Shopping

While SHW packages and integrated component assemblies can greatly simplify system installation, it is still up to the installer—or the do-it-yourselfer—to choose the correct equipment to suit a specific customer and site. The first thing a buyer should insist on is that components are certified by the Solar Rating and Certification Corporation (see Access). Shop around and understand the relative merits of each system—one pump or two; bronze, stainless, or cast-iron pumps; larger or smaller heat exchanger; Underwriters Laboratories certified controls; particulate filtration—enough differences exist between systems to require a consumer to tread carefully.

The expense of on-site assembly and the need to guarantee long-term system performance may make pre-assembled solar hot water systems the wave of the future. With a number of pre-assembled system manufacturers in the market, there has never been a better time to install a solar hot water system on your home.

Heat exchanger, pump, and control package from Oventrop.

Courtesy www.oventrop-na.com

Access

Dan Gretsch is a registered professional engineer with 15 years of experience working on energy efficiency projects. He has managed industrial energy efficiency projects in the United States, Europe, and Central and South America. He is vice president of engineering for SolarH_2Ot (www.solarhotusa.com) in Cary, North Carolina.

Solar Rating & Certification Corporation • www.solar-rating.org

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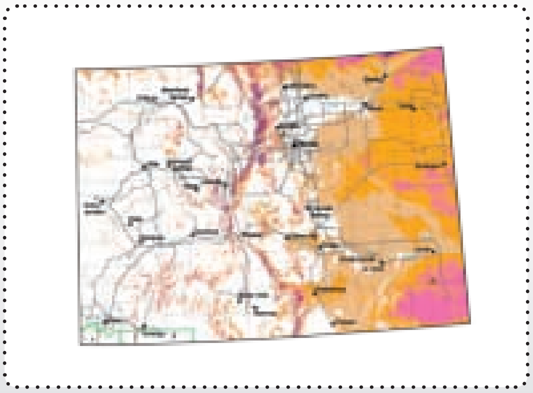
TOOLS
OF THE WIND-ELECTRIC TRADE

by Ian Woofenden

Designing and installing a home-scale wind-electric system takes knowledge, experience, smarts, strength, and courage. Working on these systems should not be taken lightly. At a minimum, get training and experience before you install your own system. If you're planning to go into the business of designing and installing systems, apprentice with an experienced and reputable wind installer first.

system design tools



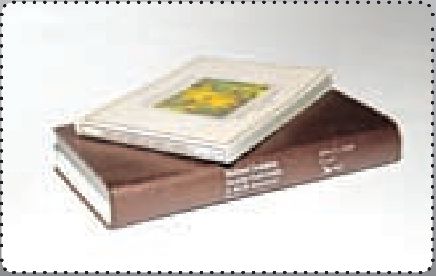
Courtesy Wind Powering America

WIND RESOURCE MAP, TOPOGRAPHICAL MAPS, AERIAL PHOTOS & GPS

These tools will help you get a sense of the site's topography, potential home and tower sites, and a general idea of the wind resource in the area.

DIGITAL CAMERA

Photos of the site will help you remember details when you're back at your desk, designing your system. Shots from trees or nearby hills can help with siting and tower height decisions.



Shawn Schreiner (2)

TREE REFERENCE BOOKS & MEASURING ROD

Knowing mature tree height is crucial to determining tower height at your site. In addition to tree reference books, a calibrated rod can help measure existing tree and building heights.

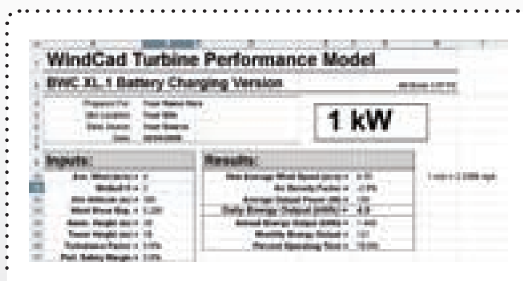
Siting, installing, and maintaining home-scale wind-electric systems require both specific knowledge and specific tools. Whether you'll be designing and installing one system or dozens, you need the right tools for the job. Basic hand tools, such as wrenches, sockets, and screwdrivers used for any mechanical work, should certainly be in your toolbox. And you will need the tower, turbine, and other equipment manuals to facilitate your installation.

Beyond these things, the gear shown here is the most important equipment for the jobs at hand. If you're only going to install one system, you may be better off borrowing or renting some of these tools, or hiring a professional for certain parts of the project.

Some of the tools listed are specialized; others are common. Some will only be used once; others will be useful for maintenance and analysis throughout the life of your wind system. Once you have the mechanical, construction, and safety skills necessary for installing a wind-electric system, having the right tools for the job will make your wind installation job better, faster, and safer.

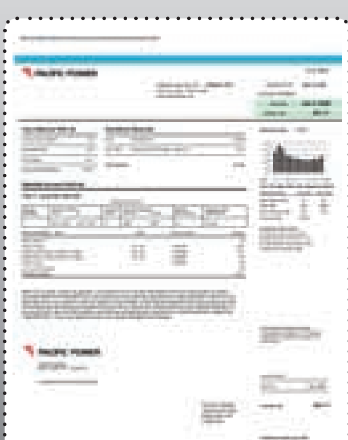
RECORDING ANEMOMETER

For larger wind projects, datalogging the wind resource at the site is vital to making an accurate projection of energy production. An anemometer allows you to measure average and peak wind speed. It may also measure wind direction, energy density, and wind distribution.



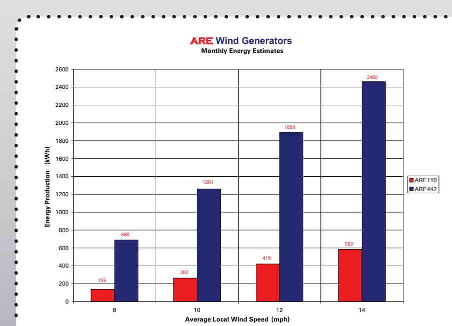
WIND OUTPUT CALCULATOR

A comprehensive wind output calculator, such as WindCad, can estimate wind energy production for a specific turbine based on your site's characteristics. A number of manufacturers have these spreadsheets available on their Web sites.



ENERGY USAGE HISTORY

For on-grid installations, recent utility bills will show your average monthly energy use in kilowatt-hours (KWH), which you can use to size your turbine correctly. For off-grid homes and houses in the design stage, you'll need to do a detailed energy analysis to determine what your energy needs will be.

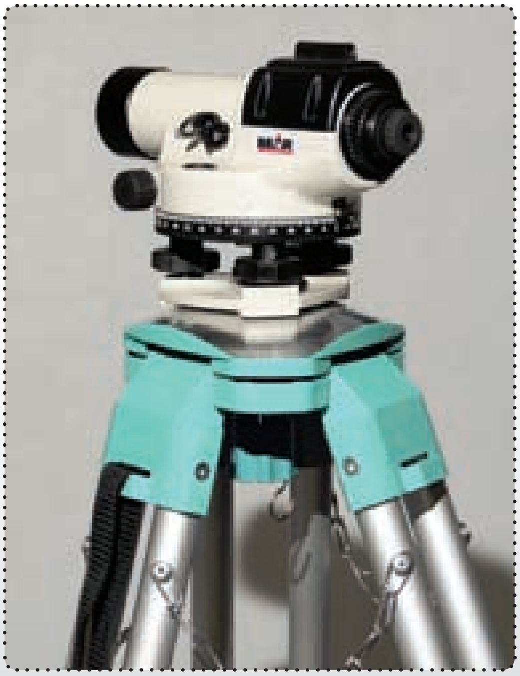


TURBINE ENERGY-OUTPUT CHARTS

Any turbine manufacturer worth doing business with will provide estimated annual energy figures (in KWH) for their turbines in a variety of average wind speeds.

Clockwise, from top left: Courtesy NRG Systems; Bergey Windpower Co.; Abundant Renewable Energy

tower & turbine assembly tools



TRANSIT OR WATER LEVEL
Either of these tools will allow you to set tower base and anchor points, and the transit can help you make a tower plumb.

SMALL GREASE GUN & NEEDLE TIP
Most modern wind turbines don't require a lot of greasing, but it's important to do it well. This small gun gets grease into the places you need to.

Shawn Schreiner (3)

CORDLESS RECIPROCATING SAW
With its ability to cut a variety of materials—metal, wood, and plastics—even in hard-to-reach places, this increasingly common tool often becomes one of the handiest on the job.

GROUND-ROD DRIVER

Grounding is critical for wind generator towers and renewable electricity systems, and this tool makes the labor-intensive job of getting the 8-foot-long rods in the ground much easier.

HOLE SAWS & STEP BITS

Electrical work almost always involves putting holes in wood, metal, or other materials. These tools cut smooth-edged holes of various sizes with minimal effort.

Shawn Schreiner (3)

TAP & DIE SET

Too often, wind system studs and threaded holes are gummed up with crud or galvanization. A tap and die set allows you to clean them with ease.

tower & turbine assembly tools

200-FOOT TAPE MEASURE
Measuring tower guy radius, tower layout footprint, and obstruction heights are a few of the jobs that this tool can assist with.

Shawn Schreiner (2)

CORDLESS IMPACT DRILL & DRIVERS
Attaching cable clamps and other tower and turbine hardware is a snap with a cordless drill. Having the impact-driver feature helps loosen stubborn fasteners.

CORDLESS ANGLE GRINDER

Cutting guy wires to length is one common use for this tool on a wind installation site, and other cutting and grinding jobs become easier with it on hand.

Shawn Schreiner

SPUD WRENCHES & ALIGNMENT PUNCHES

With guyed lattice and freestanding towers, getting the bolt holes to line up is often a challenge. So having these tools—known to tradespeople as spud wrenches and spuds—is essential while aligning parts.

TORQUE WRENCH

Tower and turbine fasteners often have torque specifications, and this tool lets you accurately tighten nuts and bolts to meet specs.

ELECTRICAL TOOLS

Electrical work requires a mix of specialty electrical tools. Shown here are some of the tools used most frequently for the electrical side of wind-electric installations.

Shawn Schreiner

climbing & rigging gear

RIGGING GEAR
Raising towers, installing wind turbines, and doing tower and turbine work require rigging skills and rigging gear, such as blocks, carabiners, shackles, cable grips, and grip hoists.

CLIMBING HARNESS & CLOTHING:
Trained climbers working on guyed lattice or freestanding towers need to be equipped with steel-shank boots, gripping gloves, a full-body harness, lanyards, and closeable tool bags.

CRANE WITH LIFTING SLINGS
Using a crane to lift a fixed-guyed or freestanding tower, or a turbine onto a tower, is often the safest and most cost-effective option, allowing almost all assembly work to be done on the ground before the lift. Careful project planning is needed to minimize the time spent with this high-dollar rental.

FALL-ARRESTING DEVICE & CABLE
Any climbable tower should have a fall-arresting system, such as a Lad-Saf cam-locking device and its dedicated cable. Gravity is unforgiving! Don't take chances with your life.

Access

Ian Woofenden (ian.woofenden@homepower.com), one of *Home Power*'s senior editors, lives with wind energy, teaches workshops on wind energy, consults about wind energy, and gets involved with wind installations on a regular basis. He is looking to better his current tallest tower installation record of 167 feet.

Thanks to veteran wind-electric system installers Mick Sagrillo, Roy Butler, Randy Brooks, and Hugh Piggott for contributing their lists of essential tools. And special thanks to Jim Thayer at Ashland General Hardware, Ashland, Oregon; and Pacific Survey and Medford Tool, both of Medford, Oregon, for allowing us to photograph their tools.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Avoiding Common Code Mistakes

John Wiles
Sponsored by the U.S. Department of Energy

Eight years into the new millennium, the PV industry continues to grow by leaps and bounds. New module and inverter manufacturers are entering the market, and the number of PV system installers is growing right along with the demand. Numerous small residential and large commercial PV systems are being installed in many states, and all need to be in compliance with the *National Electrical Code (NEC)* and any local electrical codes. With new people entering the industry every day, the *NEC* installation mistakes we have seen in the past will likely continue. Here are some of the most common ones that should be avoided.

DC Module Wiring Color Codes

Back in '97—that is, *1897*—when the first edition of the *NEC* was being drafted, Thomas A. Edison was generating electricity. This was direct current (DC), not that AC stuff with its heavy, costly transformers developed by Westinghouse and/or Tesla. So the earliest *NEC* dealt with DC, including color coding for conductors that still holds today. If the conductor is a grounded circuit conductor, the insulation or marking on larger conductors must be white or gray. If the conductor is an equipment-grounding conductor, it must have green or green with yellow-striped insulation—or be bare. Ungrounded conductors may be any color other than the ones listed above, with black and red being the most common in the field.

Those color codes apply to both AC and DC electrical systems. There is no separate color code for DC systems. Nearly all past PV systems and those being currently installed are grounded systems, and one of the conductors in the DC parts of the system should be white. PV installers insisting that red is positive and black is negative are to be relegated to their *electronics* workbenches, where such color codes are common.

In the future, we will see the installation of ungrounded PV arrays that will be used with transformerless inverters, and those systems will not have a grounded PV DC conductor. (See *NEC* Section 690.35.) At that time, the use of red and black conductors may become more common, but, presently, this is incorrect on grounded systems.

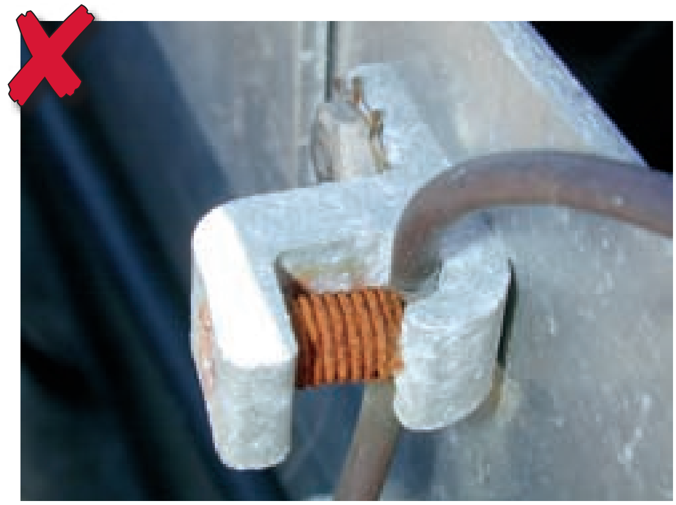
Grounded PV source circuits, but no white conductors.

Module Grounding

Module grounding still continues to be an issue with many inspectors, and rightly so, as PV installers attempt to reduce the time and materials required to ground modules. In September 2007, Underwriters Laboratories (UL) issued an interpretation of the UL Standard 1703 for PV modules requiring that module manufacturers identify the grounding method and materials to be used in grounding the modules. UL will then test and evaluate those methods and materials, both during the listing of new modules and the periodic recertification of existing modules. It is likely that the common use of a thread-cutting screw will not survive these new evaluations, which require that all threaded electrical connections be installed and removed ten times without damage to the threads.

Until those more definitive requirements come into play, *NEC* Section 110.3 requires that the labels and instructions provided with listed/certified modules be followed for proper module grounding. That usually means attaching a conductor or a tin-plated copper direct-burial lug to one of the four grounding points marked on the module frame. Attaching lugs properly is a time- and materials-intensive process, and it is hoped that better procedures and materials are developed and approved quickly.

Improper module grounding with dissimilar metals.



A dry-location lug used in a wet location.

Improper enclosure grounding: wrong device, wrong location.

A listed ground-bar kit in the proper location.

Enclosure & Conduit Grounding

Most utility-interactive PV systems operate at DC voltages between 300 volts and 600 volts, making proper grounding of the metallic enclosures used for disconnects and source-circuit combiners essential. Under *NEC* Section 250.8, using sheet-metal screws to ground enclosures is not allowed, although some PV installers and electricians continue to do so.

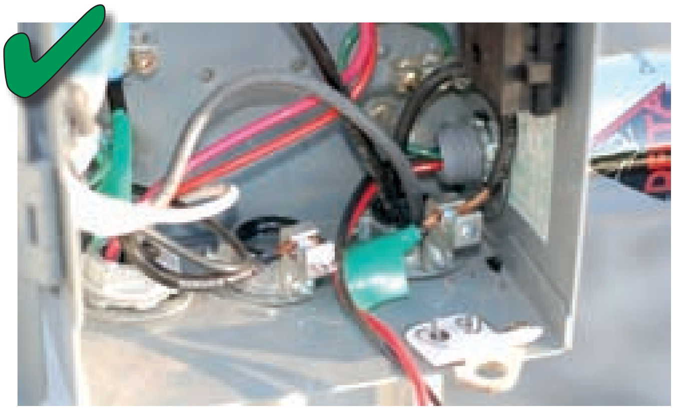
In listed safety disconnects, there is usually a label requiring the use of an appropriate, listed, ground-bar kit to ground the enclosure, and designated areas of the enclosure where the metal has been swaged thicker. This allows two full threads of the ground-bar kit's thread-cutting screw to cut into the enclosure. Failure to use the proper ground-bar kit would appear to violate 110.3(B) and could result in an enclosure that is not properly grounded.

NEC 250.97 requires that metal conduits containing circuits operating at more than 250 volts be properly bonded to the enclosures, particularly when concentric and eccentric knockouts are involved in the large enclosures used for disconnects.

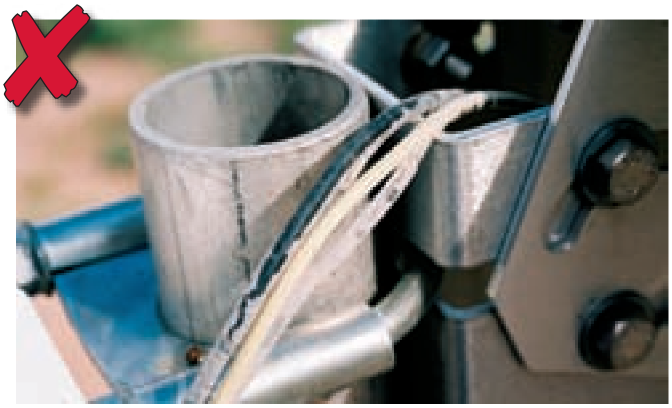
Disconnect Connections

Typical fused and unfused disconnects (a.k.a. safety switches) usually have their "line" terminals (usually the top set of terminals) shielded by an insulator. This prevents these terminals, when energized by a source, from being easily touched when the cover or door is open. Normally, a mechanical interlock between the handle and door requires the disconnect to be turned off before the door can be opened. With the disconnect in the off position, the blade contacts and the lower set of "load" terminals, which are exposed and not covered with insulation, are not energized—and supposedly safe. This setup works well when the only source of power is connected to the line terminals and loads are connected to the lower load terminals.

PV systems with multiple sources of power and power flows confuse the issue somewhat. A PV system's DC disconnect should have the line terminals connected to the incoming PV output conductors. The inverter DC input should be connected to the load terminals on the disconnect. However, energy storage and filtering capacitors in the inverter can energize the inverter DC input terminals and



Bonding bushings on 500 VDC conduits.



Deterioration of THHN conductors due to outdoor UV exposure.

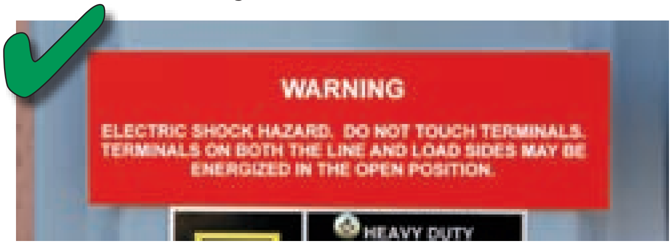
the disconnect load terminals up to five minutes *after* the disconnect is opened. These energized load terminals are the reason for Section 690.17's requirement that a warning label, stating that all terminals might be energized, even when the disconnect is opened, be placed on the disconnect.

Sometimes, installers (and inspectors) get confused when a safety switch is used as the AC inverter disconnect. These disconnects are frequently required by the local electric utility or may be part of a service-entrance tap for the PV system. Electricity flows from the inverter to the utility, usually through a backfed circuit breaker. Some installers and inspectors want the upper line-side terminals of the disconnect to be connected to the source of energy, the inverter. However, the normally energized conductors from the utility are the most dangerous and should be connected to the upper or line terminals of the disconnect. When the disconnect is opened, the inverter immediately ceases producing power, and the load terminals and the exposed blades of the disconnect have no voltage on them. Because the load terminals are de-energized when the disconnect is opened, there is no requirement for a 690.17 warning label on this disconnect when it is connected properly.

Improper Conductors

PV modules operate in extreme outdoor conditions, where temperatures on and near the modules may range from -40°F to 176°F. There is always an abundance of ultraviolet (UV) radiation (remember, it comes from sunlight) and wind, rain, snow, and ice depending on location. *NEC* Section 690.31 allows single-conductor, insulated cables to be installed as connections between PV modules and from the modules to a transition box under the PV array, where a more conventional wiring system starts. The use of the wrong conductors for exposed locations, such as THHN/THWN, RHW, THW, or others that are intended for use in conduit, will result in rapid deterioration of these conductors that have no UV resistance. Conductors marked USE-2, with or without RHW-2 markings, should be used for exposed module interconnections. Newer cables marked "PV Wire," "PV Cable," "Photovoltaic Wire," or "Photovoltaic Cable" are coming to the market, and they too will be acceptable since they have a thicker jacket and superior sunlight resistance compared to USE-2. Where this new cable is used in conduit (it has the necessary properties for that application), the conduit fill will have to be calculated manually because of the thicker jacket.

Warning label for PV DC disconnect.



Best PV Practices

PV systems are a mature, but evolving, technology. While seasoned PV installers are meeting *NEC* requirements, there is a continual influx of new equipment and new, inexperienced installers. Installers must keep up with the new equipment installation requirements while remaining vigilant for the mistakes that will inevitably continue to plague future installations.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. He provides engineering support to the PV industry and electrical contractors, electricians, and electrical inspectors with a focus on *NEC* issues related to PV systems, and is available to give six- to eight-hour presentations on "PV Systems and the *NEC*" to groups of 40 or more inspectors, electricians, electrical contractors, and PV professionals.

Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

The Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist & previous *Code Corner* articles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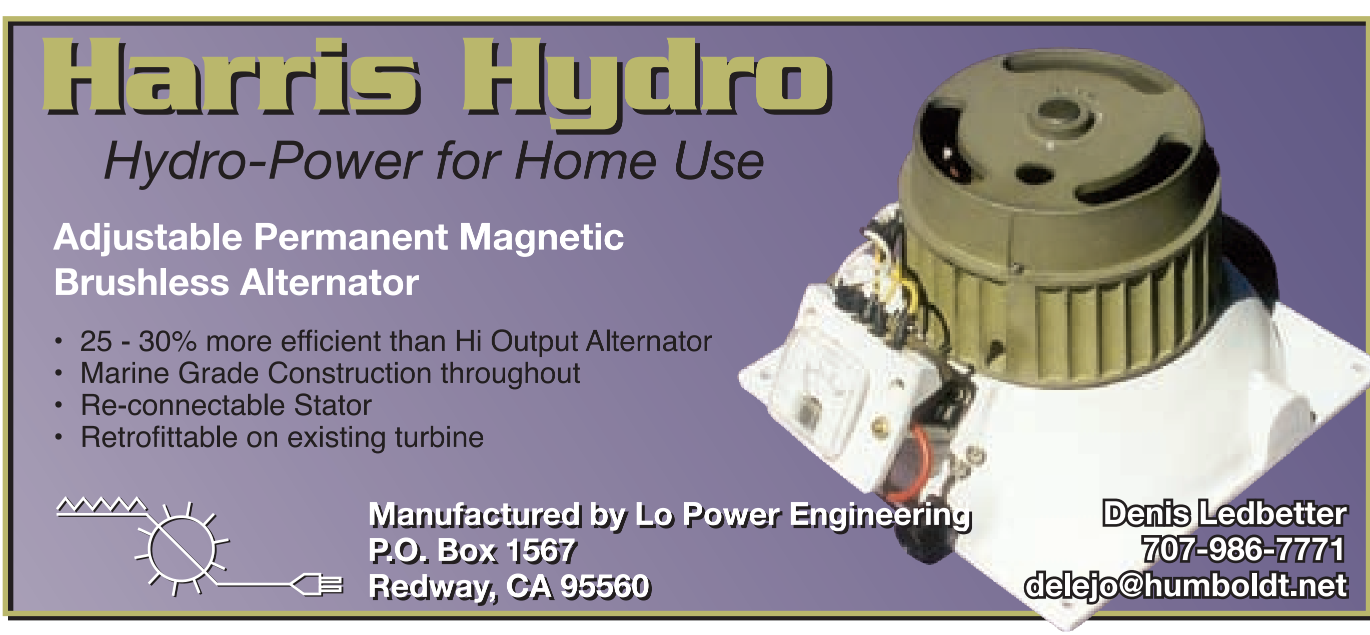
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Incentives:

The Solar Stimuli?

by Don Loweburg

PV incentive programs, be they in Europe, Japan, or the United States, have played a huge role in the development of a global PV market. The World Watch Institute reports that global PV production increased 41% in 2006 to 2,521 megawatts. Compared to global PV production in 2000 (about 400 MW), this is a 600% increase.

In the United States, state and federal tax credits have leveraged state incentives. The 30% federal tax credit implemented in January 2006 under the 2005 Energy Policy Act has especially heated up commercial PV projects. During 2007, the California Solar Initiative program reported a doubling of the number of commercial reservations when compared to 2006. Unfortunately, this increase hasn't been the case across all sectors: A $2,000 cap on residential tax credits has resulted in higher final costs for these system owners and may be responsible for the relative slowdown of California residential PV projects.

The Incentive Impetus

Incentive programs vary widely, some simply providing a direct rebate to the customer that is based on the system's output rating (capacity based), while others reward actual energy production with payment provided over time rather than a single payment upon completion of the project (production based).

But whether capacity- or production-based, incentives are shaping the market for PV systems. Currently, that market consists of two primary sectors, commercial and residential. What effect has incentive structure had in determining the relative size of these two market sectors in the United States? Are there other factors outside the incentive program design that are responsible for market allocation?

The incentive programs in three states—California, Oregon, and New Jersey—provide a good sampling of successful U.S. programs. Together, these three programs account for more than 90% of PV sales in the United States and can provide a deeper look into market sector uptake.

California has had incentives for PV systems since 1998. In 2007, the program was restructured and renamed the California Solar Initiative (CSI), with the intention of providing a ten-year funding platform for PV systems. The CSI uses a capacity-based rebate for systems smaller than 100 KW, while mandating performance-based incentives for larger commercial systems. Additionally, the incentive levels decline over time as program participation increases. In early 2007, rebate levels started at $2.50 per AC watt for both residential and commercial projects. At this time of writing, California residential rebates are at $2.20 per AC watt and commercial rebates are at $1.90 per AC watt.

Prior to the CSI, the incentive program had resulted in approximate parity between commercial and residential segments of the PV market, with about 75 MW installed at commercial sites and about 100 MW installed at residential sites. A significant shift occurred in the first ten months of the CSI. Residential installations have stalled and commercial installations have escalated. According to SunCentric, an RE consultancy, predicted PV installations for residential customers in California will be about 22 MW in 2007 compared to almost 56 MW installed during the previous year. Commercial projects for 2007 are expected to exceed 130 MW, about six times the expected residential level for 2007.

Oregon's rebate program began in May 2003. Oregon's rebate for commercial systems is between $1.25 and $1.50 per rated DC watt and the state allows a generous 50% state tax credit. Residential systems get a rebate of $2 to $2.25 per rated DC watt and a state tax credit of $3 per DC rated watt, capped at $6,000. Jan Schaeffer, communication and marketing director for the Energy Trust of Oregon (ETO), reports that the 2007 expenditure of $3 million will increase to $9 million in 2008 with additional funding for commercial systems approved in April 2007.

Currently, about 1.3 MW of residential and about 0.7 MW of commercial systems have been installed under Oregon's program. However, Schaeffer expects commercial systems to significantly increase this year based on the funding approval of three large projects that will total up to 5 MW. In Oregon, large systems are individually negotiated by the ETO board. These projects result through the ETO's Open Solicitation program, requiring board approval of projects involving Energy Trust incentives of this scale. In 2008, commercial-installed MW are expected to exceed residential MW in Oregon by about three to one.

New Jersey. On the opposite coast, New Jersey's incentive program, Customer On-Site Renewable Energy (CORE), began in March 2001. This program initially had a generous rebate of $5 per installed watt. But the high rebate coupled with federal tax credits resulted in a very high program uptake, quickly depleting the program's funds. According to the program's Web site, as of October 2007, 2,351 PV projects have been

installed. During 2007, the residential sector installed about 2.5 MW, while the commercial sector accounted for about 7.3 MW. The New Jersey program is not approving projects until more funding can be secured. According to the CORE Web site, a backlog of 8.3 MW exists for residential systems and there is a 26.7 MW backlog for commercial systems.

Accelerating Growth

Within these three incentive programs, the subscription for commercial systems is running between three and six times greater than that for residential systems. However, it is difficult to attribute this significant difference to any specific structural elements in these programs. For instance, Oregon offers a modest rebate of $1.50 per watt compared to New Jersey's generous $5 per watt. This difference may explain the oversubscription and current struggles that the New Jersey program faces, but does not account for the imbalance between residential and commercial systems. Examining incentive type, whether capacity- or production-based, also fails to explain the imbalance. California offers both, while the other two programs offer only capacity-based rebates. So what's the dynamic driving the expansion of commercial systems?

Federal business tax credits coupled with an investment model known as a Power Purchase Agreement (PPA) can explain the disproportionately rapid growth of the commercial PV market. The federal investment tax credit (ITC) allows for 30% of a PV system's cost to be deducted from any federal taxes due, with no commercial systems cap. For residential systems, the ITC is capped at $2,000. Additionally, business investors can take advantage of the Modified Accelerated Cost Recovery System (MACRS), which allows the investment to be depreciated over a five-year period.

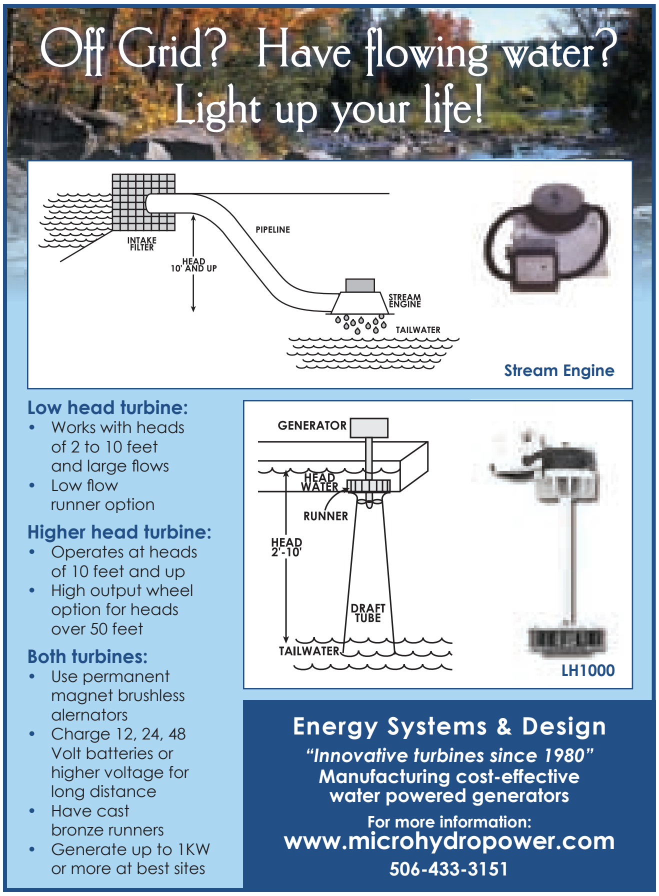
Under one type of PPA, an investor or group agrees to sell the power produced by their PV system to a host client. The host does not own the system but does agree to provide a site for the system and to purchase the electricity produced for a fixed number of years at either a fixed rate or at some rate indexed a fixed amount below the utility price for electricity. Investors receive the incentives offered by the local program, a five-year accelerated depreciation for their investment, and a 30% tax credit. Plus, they retain the value of any renewable energy credits (REC). In addition, investors receive cash flow coming from the sale of project's power to the host customer. The host saves on electricity costs and can claim "green" bragging rights, both with no financial investment.

Jump-Starting Residential Growth

Investors do deserve to make profits and these, in turn, help drive the PV industry forward. However, when one sector dominates, it may be to the detriment of another. The strength of the U.S. economy is not based solely on corporate investment, but also relies strongly on consumer spending. Balance in markets, as balance in life, needs to be sought. Removing the $2,000 cap on the federal residential tax credit could be a powerful stimulus for the residential PV market in the United States.

Access

Don Loweburg (don.loweburg@homepower.com) and his wife Cynthia run Offline Independent Energy in central California from their off-grid office and home. Don and his crew of two handle installations, while Cynthia manages the business. Offline projects include both grid-tied and off-grid systems. Don also enjoys teaching college-level algebra at a local junior college two evenings a week.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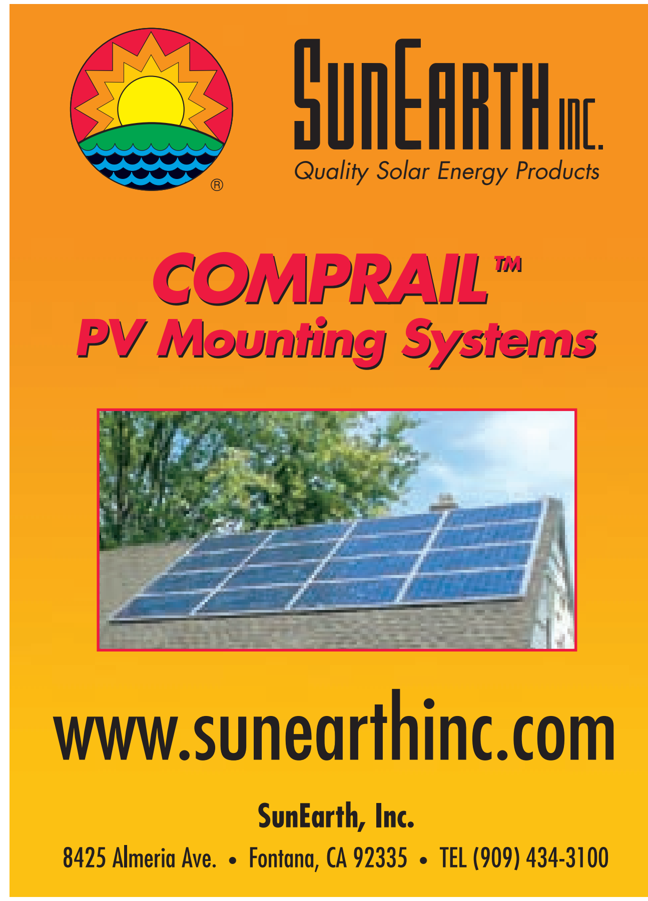
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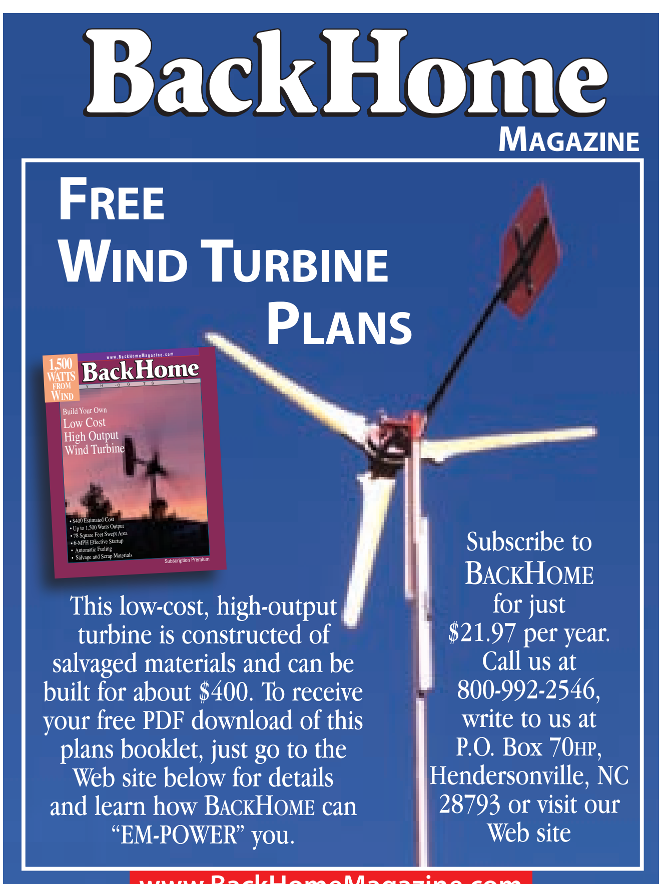
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Focus the Nation

by Michael Welch

According to the League of Conservation Voters, since January 2007, the hosts of popular news shows on five major TV networks—ABC, NBC, CBS, Fox News, and CNN—have asked the presidential candidates almost 3,000 questions. Of these thousands, only *six* mentioned global warming. Six. That calculates to about two-tenths of 1%—and is about the same number of questions posed to the candidates about UFOs.

Is anyone besides me wondering why reporters are ignoring one of the most urgent threats to humanity?

I guess it's not much of a mystery, considering that for-profit corporations, which are legally required to put shareholder profits ahead of all other considerations, own almost all media in the United States. Many are also heavily invested in or even owned by energy companies (for example, General Electric, which owns NBC) and have board members who sit on the boards of other corporations, including oil companies and defense contractors.

Major media relies largely on advertising sales, so little impetus exists for them to focus on anything other than programming that maximizes ad revenues. Nor is there any incentive for their advertisers to support programming that deals with topical issues that could possibly countermand the need or desire for the products and services being hocked.

But six measly questions? Jeez.

Pointing to the People

Of course, we cannot put all the blame on the media for not focusing on this all-important issue, when our citizenry is not paying much attention to it, let alone making the needed lifestyle changes. One morning I was reading a local newspaper, which publishes "person on the street" responses to particular questions. The question that day asked what issues were most important for presidential candidates to address. Not one of the five respondents mentioned energy or climate as a priority. The fact that these answers came from people in southern Humboldt County—a hotbed of rural social and political activism—shocked me. Especially considering that it's also a community well versed in renewable energy, having more RE-powered homes per capita than any other region of the world.

But maybe I shouldn't have been surprised—even those of us "in the know" are having trouble dealing with the issue. Most of us involved in the local Redwood Alliance Climate Action Project, a volunteer group addressing global warming education and advocacy, struggle to make the needed changes in our lives that could help turn around climate change. Most of us still buy clothing, furniture, and appliances made overseas and shipped at huge energy costs. We still buy imported fruit, vegetables, and grains, rather than locally grown produce. And we are still having trouble cutting back significantly on the energy use in our homes and workplaces. Probably worst of all, we are driving our vehicles way too much—it's too convenient, fuel is still relatively inexpensive, and few public transportation options exist.

When so many who are already aware and active in global warming education are having trouble stepping up, it makes me think about what's really needed to pull off a major reduction in greenhouse gases (GHGs) to keep Earth hospitable for us humans. Those thoughts have led me to a conclusion that I am struggling with—rather than relying on ourselves, we may have to rely on politicians and the political process to make the sweeping changes needed to stop human-caused climate change.

More and more, I think that global warming won't be stopped without governments worldwide enacting and enforcing laws, and our own government taking the lead—both because we can set an example and because our consumptive American lifestyle makes us one of the world's leading GHG contributors.

We Can Demand...

This is not going to be easy. Too many politicians are used to favoring business over the citizenry, so a lot of citizen contact will be needed to overcome the corporate favoritism. The good news is that groups across the nation are already gearing up to push for decreases in CO_2 emissions, and many are targeting politicians and asking their memberships to do the same. And there are powerful allies within the scientific community who are stressing the science behind climate change. The science is hard to deny, and political leaders won't have easy excuses to ignore the need to make climate action a high priority.

The minimum need, as recognized by scientists and astute politicians and individuals, is to make sure that worldwide GHG production is reduced by 70% to 80% less than 2000 levels. This needs to be accomplished by 2050 to avoid a temperature increase that we might not be able to recover from—the "tipping point." Under that scenario, GHG emissions from all nations are assumed to peak within about 15 years, so we must begin working toward the decrease soon.

With that goal in mind, here's a sampling of what we citizens should be asking our politicians for, en masse:

- Require even greater vehicle fuel economy. Forget about the measly 45 to 55 mpg that is attainable only in the most fuel-efficient vehicles of the day. We want 100 mpg vehicles with low emissions to match. We need to stop letting auto manufacturers and oil companies dictate what we get—it is time to force them into dealing with the global warming issues that they have largely created.
- Improve and increase mass transportation options—everything from buses to light rail to regional trains, and with ridership incentives to help wean folks from their single-passenger car commutes.
- Take away corporate welfare for the coal, oil, natural gas, and nuclear industries. It is time to put all of our energy subsidy dollars into technologies that are safe, clean, and renewable.
- Help big business get involved in RE by giving them incentives to design, build, and sell clean-energy products and fuel-efficient vehicles. The profit carrot will be as, if not more, helpful for them as the regulatory stick.
- Cap the amount of greenhouse gases that nonrenewable-fuel-based power plants are allowed to produce at levels equal to the amount produced by renewable-fuel-based plants. Make the fines for exceeding the caps significant, since the financial bottom line is the only thing that forces energy corporations to act. Allow CO_2 trading to encourage power plants to reduce their carbon outputs even further below the caps.
- Pay utilities to decommission their polluting plants in favor of ones that create fewer GHGs and other pollutants. Again, the carrot.
- Establish incentives for appliance manufacturers to produce highly efficient products, and add personal incentives so that even low-income households and small businesses can afford to upgrade to more efficient appliances.
- Fund incentives that encourage energy conservation in homes and businesses—particularly where heating, air conditioning, and lighting are concerned.
- Increase nationwide tax credits and per-KWH incentives for the installation of RE systems on homes and businesses. Implement a nationwide net metering program that pays at retail rates, even for excess energy generated at the end of the year.
- Stop the deforestation of tropical rainforests, and begin reforesting those areas that have been decimated.

Time for Change

So while our major media reflects the corporate stance of downplaying global warming, and while progress is slow on the individual front, what we all can do is get grounded in the facts and hold the politicians' and bureaucrats' feet to the fire. We need to focus our nation and the world on the cure for human-caused climate change, and the time to start is now, in preparation for the race for the presidency this fall.

What can you do? For a start, write and call the candidates, as well as legislators and other federal politicos. Let them know that stopping global warming is important to you. Contribute both finances and personal energy to the campaigns that promise to make the biggest difference—a strategy that will help offset the money being loaded into the campaigns by the fossil-fueled business-as-usual interests that prefer short-term profits over long-term planetary survival. Finally, write the newspapers and other media about your concerns that candidates are not addressing this all-important issue. Let's take this back into our control, by focusing the nation on this most important of issues.

Access

Michael Welch (michael.welch@homepower.com) has been working for a clean, safe, and just energy future since 1978 as a volunteer for Redwood Alliance and with *Home Power* magazine since 1990. He is working to shrink his environmental footprint, and to make sure politicians and corporations also do their share.

Climate Science:

Intergovernmental Panel on Climate Change • www.ipcc.ch

RealClimate • www.realclimate.org

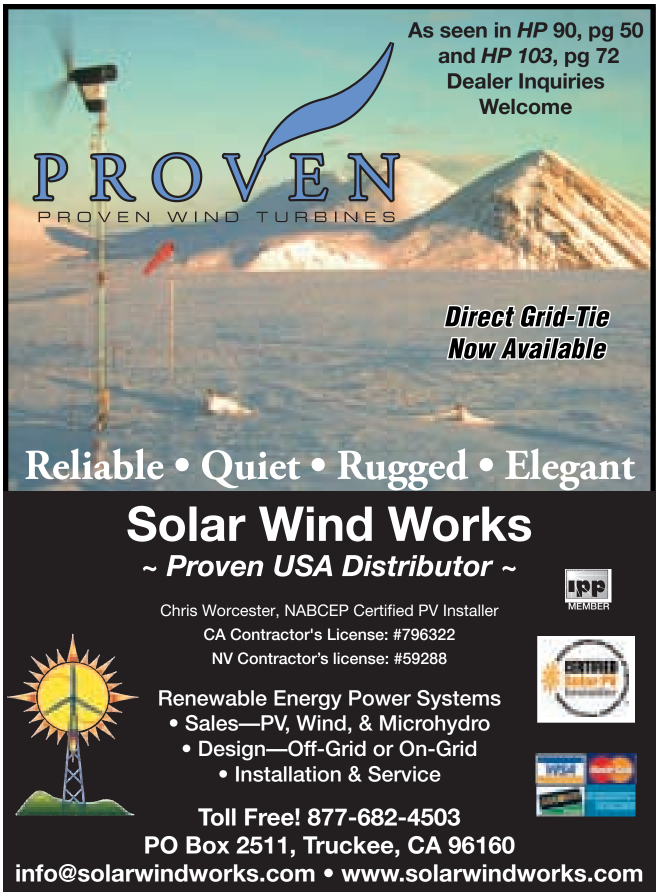
Union of Concerned Scientists • www.ucsusa.org/scientific_integrity

Climate Education & Advocacy:

"Carbon-Free & Nuclear-Free: A Roadmap for U.S. Energy Policy" • www.ieer.org

Focus the Nation • www.focusthenation.org

League of Conservation Voters • www.whataretheywaitingfor.com • Information on major media questions asked of presidential candidates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Recycle Yourself

by Kathleen Jarschke-Schultze

I've never really talked about my cancer in this column, but being diagnosed five years ago with colon cancer changed my priorities in a hurry. Although I've been in remission for several years and the chance of a recurrence is slight, cancer has robbed me of something.

Since I was eighteen years old, I have voted in every election I was eligible for, I have donated blood regularly, and I have been signed up as an organ and tissue donor. Now cancer has denied me the last two. I feel like my last noble act has been taken from me. I do not want a useless death—on the other hand, I'll make great compost.

This is a story about organ donation. In terms of sustainability, I think of it as the ultimate in recycling. I'm not out to offend anyone, but I feel this is an important subject. I couldn't think of any amusing headings, so it's the straight stuff. If you are interested, read on…

Out of Sorrow

My sister Mary is a critical care nurse, working in the hospital unit that used to be known as "intensive care." There, she regularly witnesses people making life-or-death decisions for themselves or loved ones.

Recently, a young man came under Mary's care. He had been depressed and tried to kill himself. He succeeded only in killing his brain. His brother was heartsick and trying to make sense of a senseless act. While talking to the brother, Mary asked if he thought the young man would have ever offered to be an organ and tissue donor.

He said yes, he thought his brother would have done that. Here was some good that could come from tragedy. Mary said she would start the process, bring him the paperwork, and help him through it.

But when Mary approached her supervisor about the procedure, she found out that her small-town hospital had never processed an organ donor. True to her nature, Mary volunteered and jumped right in to contact the appropriate agency and facilitate their involvement.

Preparation

There are 59 federally designated organ procurement organizations (OPOs) in the United States. All of them follow regulations and policies set by the United Network for Organ Sharing. Once a donor is diagnosed as having no brain activity, the OPO coordinator is dispatched. The donor then comes under the care of the OPO. Mary took her orders from the coordinator from that point on.

The donor was already on a ventilator, and was administered medications to maintain blood pressure and other bodily functions. Mary made a comment that I cannot forget: "It's hard to keep a dead man alive."

Many, many tests are done on a donor to determine organ health and suitability. For example, if the donor has hepatitis C, their organs can be matched to hep-C-positive recipients. Once the organs are deemed suitable, the OPO searches its waiting list for recipients. If matches are found, the donor's medical records are sent to the potential recipient's doctor. That doctor has two hours to accept or reject the organ. This process is repeated until all the organs have a specified recipient.

Then it's time for the transplant teams to converge. There are two sets of teams for each organ. Once the recovery surgery starts, if one of the surgeons deems that an organ is unsuitable for their patient, another surgeon is waiting with his or her team to step up and recover the organ for another patient.

Recovery

A time was set for the organ recovery from the young man. The surgical recovery teams converged at the hospital. Mary met all the surgeons and their teams. When everyone had moved into position around the donor on the operating table, it was standing room only. The heart surgeon from the University of San Francisco Medical Center had Mary get a sturdy chair to stand on so she could see over their shoulders. Since she was integral to this organ-recovery surgery—the first at her hospital—he wanted her to see every phase of it.

So Mary is on the chair, and the procedure is about to begin, when the heart surgeon turns to her and says, "Do you have the internal defibrillators?" Having never had an organ recovery performed there before, there were none at her hospital. Mary jumped down from the chair and used the operating room phone to call the closest hospital. No go. She called the next closest hospital, and reached a woman who said she would find out and call back in half an hour. "No," Mary insisted, "I am waiting on the line while you go *right now* and find out." The woman returned to the phone promptly. They had two sets of the defibrillators. Mary asked, "What's the fastest way you can get them here?" By helicopter was the answer. "Do it!" Mary said. She told me later she hoped they wouldn't take it out of her pay.

The heart surgeon decided to start the recovery. Inside, the walls of the operating room were lined with medical ice chests. Outside, ambulances waited to speed the teams back to the small airport. Mary climbed back on her chair. Once the heart surgeon stops the beating heart, the clock starts, ticking off the limited time for harvesting. The other surgical teams quickly move in and begin harvesting their respective organs. One team harvests each organ. The pancreas is divided in two for two different recipients.

After the teams had left, Mary and the OPO coordinator accompanied the donor's body to the morgue. Mary said it was the most fascinating thing she had ever participated in.

As Mary told me this story, she said, "It just brings tears to my eyes to think of all those pagers going off. 'We have a heart for your husband.' 'We have a kidney for your dad.' 'We found a liver for your son.'" It brings tears to my own eyes still.

My Final Words

One day I was pondering (I love to ponder) what I would want on my gravestone. After all, why leave such an important thing to a distraught family member? With my name, Kathleen Anna Jarschke-Schultze, I've got thirteen letters of the alphabet already; a few snappy phrases and I can have all twenty-six. I've come up with "Sainted Wife" and "Beloved Sister." That gives me a total of twenty letters. I'm still pondering the last six.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is living la vida loca at her off-grid home in northernmost California.


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May 3–8, '08. San Diego, CA. Solar 2008. Tech conf. for solar & energy efficiency pros in the United States. Includes dealer/installer trainings from private companies. Info: www.ases.org/solar2008/

Jun. 9–11, '08; San Francisco. PV System Design—Producing PV design documents. For engineers & designers. Info: 707-869-9391 • www.sunengineer.com/workshops.htm

Jun. 18–20, '08. San Diego, CA. PV Summit 2008. Industry & market trends. Updates on silicon supply, PV technologies, concentrated PV, next generation thin-films, dye-sensitized solar cells, organic PV & emerging applications. Info: www.intertechpira.com

Jul. 22–24, '08. San Jose. Plug-In 2008 Conf. & Expo. Latest tech advances, market research & policy initiatives on plug-in hybrid-electric vehicles (PHEVs). Info: www.plugin2008.com

Aug. 10–14, '08. San Diego, CA. Solar Energy Applications, a part of SPIE Optics+Photonics conf. Tech presentations & courses on PV; R&D of solar concentrators & solar hydrogen. Info: www. spie.org

Aug. 16–17, '08. Hopland, CA. SolFest. RE booths, workshops & kids' activities. Food & entertainment. Info: www.solfest.org

Oct. 13–16, '08. San Diego, CA. Solar Power 2008. Conference & expo. Info: SEIA • 202-296-1688 • mglunt@solarelectricpower.org • www.solarpowerconference.com

Arcata, CA. Workshops & presentations on RE & sustainable living. Campus Center for Appropriate Technology, Humboldt State Univ. • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Sept. 20–21, '08. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative vehicles & more. Info: Rocky Mt. Sustainable Living Assoc. • 970-224-3247 • kellie@sustainablelivingfair.org • www.sustainablelivingfair.org

Crawford, CO. Solar Energy for Do-It-Yourselfers '08 workshops. Jun. 6–7: Solar Ovens, Cookers & Dryers. Jun. 14–15: Intro to PV. Jun. 27–29: Batch Solar Water Heaters. Jul. 12–13: Solar Hot Air Collectors. Info: Our Sun Solar • 970-921-5529 • www.solarenergyclasses.com

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water, space heating, alternative fuels, straw bale building, green building, women's PV courses & more. Solar Energy Intl. (SEI) • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

May 15–18, '08. Orlando, FL. Green Earth Expo. Sustainable commerce & lifestyle trade show. Exhibits, keynotes, kids' stuff, RE & EE. Info: Global Green Alliance • 877-541-0887 • www.globalgreenalliance.com

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

ILLINOIS

Apr. 11–12, '08. Bloomington, IL. IL Sustainable Living & Wellness Expo. Workshops & exhibitors, incl. RE, green building & simpler living. Info: Ecology Action • 309-556-3334 • www.islwe.org

Aug. 9–10, '08. Oregon, IL. IL RE & Sustainable Lifestyle Fair. RE booths, workshops, tours & kids' activities. Food & entertainment. Info: www.illinoisrenew.org

IOWA

Sep. 13–14, '08. Cedar Falls, IA. I-Renew Energy Expo. Workshops, exhibits, food, entertainment. Info: See below.

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

Sep. 15–17, '08. Boston. Alternative Energy Sources & Technologies. Conf. & exhibition on biomass, biofuel, geothermal, hydro, hydrogen, solar, wind & waste-to-energy. Info: www.cardellexpo.com

Auburn, MA. Seminars: Solar Basics, PV, Hot Water, Wind, RE & more. Info: CNE Solar Store • 508-832-4344 • peter@cnesolarstore.com • www.cnesolarstore.com

Hudson, MA. Workshops: Intro to PV; Advanced PV; RE Basics; Solar Hot Water & more. Info: The Alternative Energy Store • 877-878-4060 • support@altenergystore.com • http://workshops.altenergystore.com

MICHIGAN

Jun. 27–29, '08. Onekama, MI. MI Energy Fair. RE, EE, green building & alternative vehicle workshops & vendors. Food & music. Info: www.glrea.org

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW HAMPSHIRE

Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO

Jun. 27–29, '08. Taos, NM. Taos Solar Music Festival. Solar-powered music, food & displays. Info: www.solarmusicfest.com

Sep. 20–21, '08. Albuquerque. Solar Fiesta. RE & EE exhibits & workshops. Info: www.nmsea.org

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Apr. 25–27, '08. Canton, NY. North Country Sustainable Energy Fair. Youth science fair, workshops on solar, wind, biofuels, green building, energy conservation, climate change & peak oil. Exhibitors & green home tours. Info: 315-379-9466 • fair@ncenergy.org • www.ncenergy.org

Apr. 26–27, '08. Saratoga Springs, NY. Saratoga Environmental Expo. RE, EE, green building & more. Info: www.saratogaexpo.com

NORTH CAROLINA

Aug. 22–24, '08. Fletcher, NC. Southern Energy & Environment Expo. RE displays, exhibits & presentations. Info: www.seeexpo.com

Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

Apr. 17–20, '08. Portland. Northwest Solar Expo. Workshops, seminars & exhibits on clean energy. Info: www.nwsolarexpo.com

Jul. 25–27, '08. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers, family day, music, alternative transportation & Electrathon rally. EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Sep. 20–21, '08. Kempton, PA. PA RE & Sustainable Living Festival. RE, natural building & sustainable ag; workshops, speakers, exhibits, vendors, music & kids' activities. Info: www.paenergyfest.com

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

RHODE ISLAND

Jun. 7, '08. Coventry, RI. Sustainable Living Festival & Clean Energy Expo. RE workshops, vendors & music. Info: www.livingfest.org

TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

Apr. 5–6, '08. Houston. Gulf Coast Green Consumer Expo. Exhibits on green building, EE, RE & alternative transportation. Info: expo@gulfcoastgreen.org • www.houstongreenexpo.org

Sep. 26–28, '08. Fredericksburg, TX. RE Roundup & Green Living Fair. Exhibits, speakers & workshops on RE, green building, green ag & EE. Info: www.theroundup.org

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group, quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

VERMONT

May 12–7, '08. E. Charleston, VT. Solar-Electric System Design & Installation. Hands-on intro to electricity, PV modules & system components for batteryless & battery systems. Info: See SEI info under "Colorado."

Jul. 11–13, '08. Tinmouth, VT. SolarFest. Solar-powered music & RE festival. Info: www.solarfest.org

VIRGINIA

Apr. 10–11, '08. Arlington, VA. Energy Efficiency Finance Forum. The next generation in financing clean energy. Info: ACEEE • www.aceee.org

WASHINGTON STATE

Jul. 18–19, '08. Shoreline, WA. Shoreline Sustainable Living & RE Fair. Exhibitors & speakers. Info: www.shorelinesolar.org

WISCONSIN

Jun. 20–22, '08. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, green building, alternative transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '08 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. Info: 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha '08 workshops. Intro to Solar Water & Space Heating System, Installing a Solar Water Heating System, Living Sustainably & more. Info: 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

INTERNATIONAL

AUSTRIA

Apr. 6–10, '08. Vienna. Energex. Congress & exhibition. Energy for human development & the protection of the environment: policy, economy & technology. Info: Aims Intl. GmbH • 43-1-402-77-55-0 • energex2008@aimsinternational.com • www.energex2008.com

BRAZIL

May 23–25, '08. São Paulo. EcoBuilding trade show & conf. Intl. meeting for architecture & technologies for sustainable construction. Info: www.anabbrasil.org/ecobuilding2008

CHINA

May 10–11, '08. Shanghai. Chinese–European Intl. Solar & PV Exhibition and Conf. To strengthen cooperation & exchange between Chinese & intl. markets. Info: www.snec.org.cn

GERMANY

Jun. 12–14, '08. Munich. Intersolar 2008. Solar developments exhibition & forum. Info: www.intersolar.de

HUNGARY

Apr. 24–26, '08. Budapest. RExpo. Industry conf. on RE & EE for central & SE Europe. Info: Reeco GmbH • 49-0-7121-3016-0 • duong@energie-server.de • www.energy-server.com

ITALY

Nov. 7–9, '08. Milan. Casa Energia Expo. Exhibition on residential buildings that produce & save energy. Info: Artenergy • Via Antonio Gramsci • 39-026-630-6866 • press@zeroemission.eu • www.zeroemission.eu

MEXICO

Apr. 20–27, '08. Chiapas. Appropriate Technology Implementation Course. Overview of small-scale RE & resource management in the developing world. Info: Instituto Internacional de Recursos Renovables • info@irrimexico.org • www.irrimexico.org

NICARAGUA

Jul. 21–31, '08. Totogalpa. Solar Cultural Course. Lectures, field experience & ecotourism. Info: Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

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California, cont.

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4/21-22 Small Scale Wind Energy with Southwest Windpower & WNCREI staff at Beech Mountain R&D site
5/26-27 Microhydro with Don Harris and WNCREI staff at Appalachian State University
6/2 Domestic Solar Water Heating Design & Construction with Fred Stewart at Appalachian State University
6/22-23 Sustainable Community-Scale Biodiesel Production Workshop at Appalachian State University
8/29 PV and the National Electrical Code with John Wiles at Appalachian State University
9/15 Active Solar Hydronic Space Heating with Fred Stewart at Appalachian State University
9/22-23 Small Scale Wind Energy Installation Workshop with Robert Preus of Abundant Renewable Energy at Beech Mountain R&D site
10/20-21 Small Scale Wind Energy with Southwest Windpower & WNCREI staff at Beech Mountain R&D site
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RE People

Who: Dan Lewis & Jill Brandsborg
Where: Guemes Island, Washington
When: 2003 to present
What: Solar-electric system
Why: Simplicity & elegance

Shawn Schreiner (3)

Dan and Jill in front of their home.

In 1996, Dan Lewis and Jill Brandsborg left professional careers in the Denver area to simplify their lives. Jill realized that the hectic pace of the city and her teaching career was taking its toll on her physically and emotionally. She frequently recalled her childhood dreams of living in a simple and purposeful way, and realized that her fast-paced life had left those aspirations behind.

Dan was likewise struggling with the pace and the consumption in their life. "Traditional America says you work hard, get a big paycheck, get a big house, and continue paying for it for much of your life," says Dan. "We left that because it wasn't really the quality of life we wanted. For us, real quality of life is not measured by money, but how we can live."

Organization is the key to living large in small spaces.

After traveling for a few years, they found 13 acres on Guemes Island, Washington, and built a 250-square-foot cabin, carefully designed to satisfy their needs while using less. Dan and Jill initially lived without electricity, using candles and kerosene lamps. These days, they use a small amount of propane to cook and heat water; they collect rainwater and compost all their organic materials on site. Both Dan and Jill bicycle and walk a lot, and they are moving toward growing some of their own food.

Collecting rainwater is one of Dan and Jill's strategies for a more sustainable lifestyle.

What impressed me most when I first met Dan and Jill continues to impress me today: They are committed to a *thoughtful* approach to their life and lifestyle. For several months after they moved into their cabin, they had few furnishings—a mattress in the loft, a simple kitchen countertop, and a few chairs. When I teased Dan about this, he said, "We want to make sure we get absolutely what we want." They were not in a hurry to get it done; it was more important to do it right.

Given their thoughtful consideration of every aspect of their lives, it is no surprise that they chose a small PV system for their minimal electrical needs, such as lighting, water pumping, and a computer. The 600-watt system typically meets their electricity needs ten months out of the year. When there's not enough energy in the winter, Dan and Jill either go into pre-electric mode (candles), or travel to visit friends and family. They do not own a generator.

The couple's simple life reflects the land they live on, the community they live in, and their own hearts and minds. Their financial needs are minimal, with few bills, so they don't spend their lives working to pay for their lifestyle. Their example of living lightly on the land has inspired dozens of people who tour their basic but comfortable home.

Jill says that when she visits "real" people in "real" houses with "real" jobs, she knows those lifestyles "don't fit this place." She says, "Slowing down has allowed us to enjoy the beauty in everyday, simple things. Since I allowed myself to do that, I don't want to go back."

—Ian Woofenden

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